

[54] **JOINTLESS CODED TRACK CIRCUITS FOR RAILROAD SIGNAL SYSTEMS**

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[58] Field of Search **246/34 R, 34 CT, 36, 37, 246/63 C**

[56] **References Cited**

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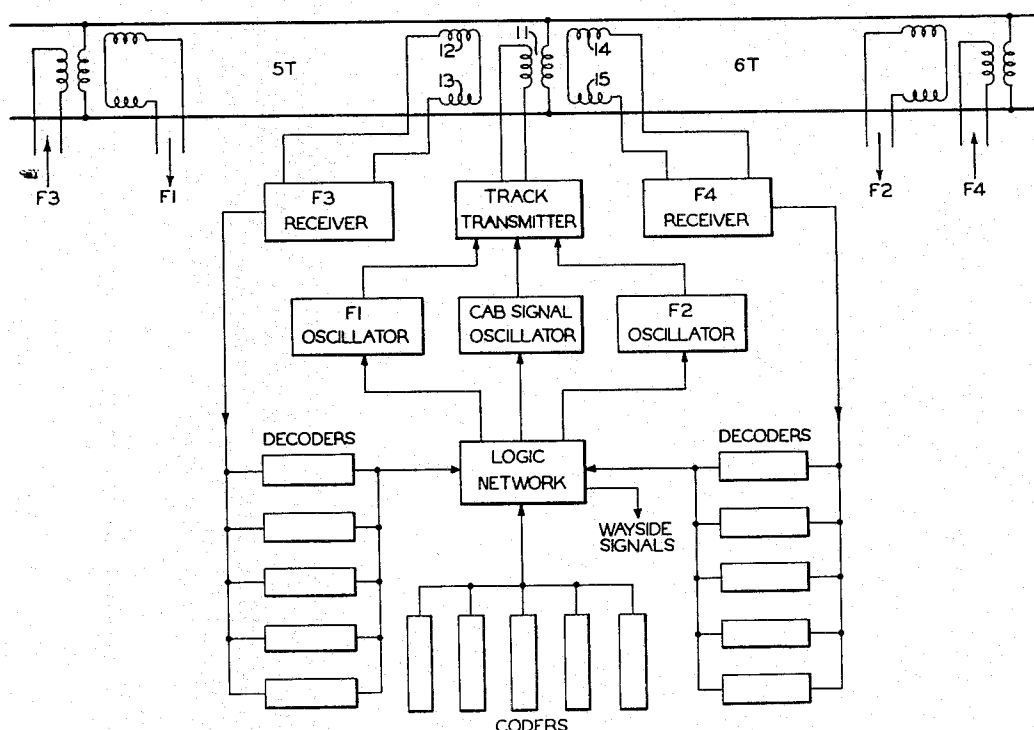
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[57] **ABSTRACT**

Track currents are supplied to the rails of adjoining sections at each location through a track transformer whose secondary serves as a low impedance cross bond to divide the track into sections without insulated joints and to confine track circuit energy to a given zone. A track transmitter develops sufficient energy for rail currents with the selected different frequencies established by a separate oscillator unit for each adjoining section. A tuned track receiver for each section is independently coupled by pickup coils to the corresponding section rails in the vicinity of the cross bond to receive incoming track current of a different frequency from the other end. Each track current is coded at a selected rate in accord with corresponding advance traffic conditions. A received track current signal is demodulated by the corresponding receiver and applied through decoding units to a logic network which detects track section occupancy and determines the traffic condition. In accord with the registered traffic or occupancy conditions, the logic network selects from code rates provided by a bank of coding devices for modulating the applied track currents. The selected code rates modulate each oscillator output and thus the track transmitter output. If cab signals are used, a separate oscillator, also controlled by the logic means, supplies coded cab signal energy to an approaching train through the track transmitter.

12 Claims, 2 Drawing Figures



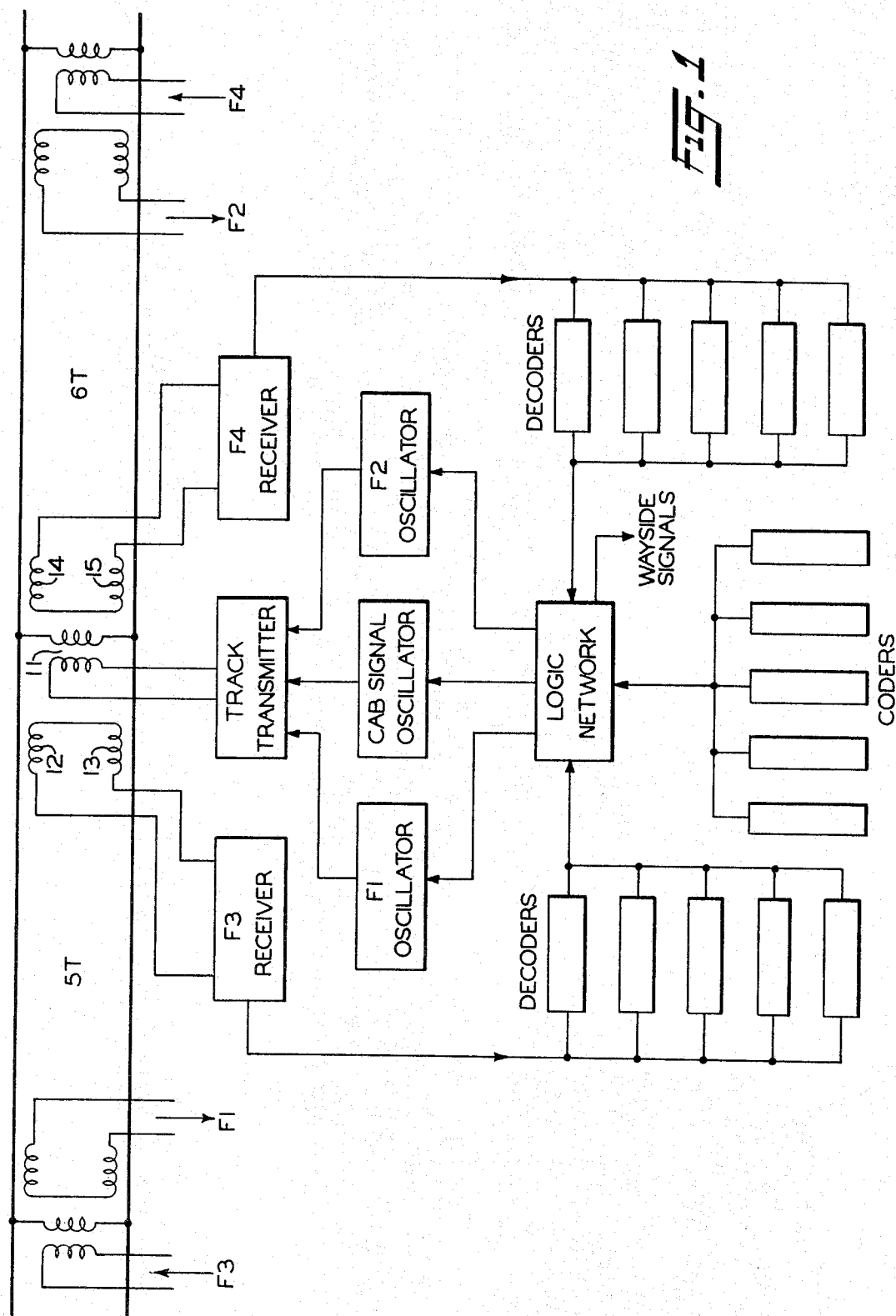
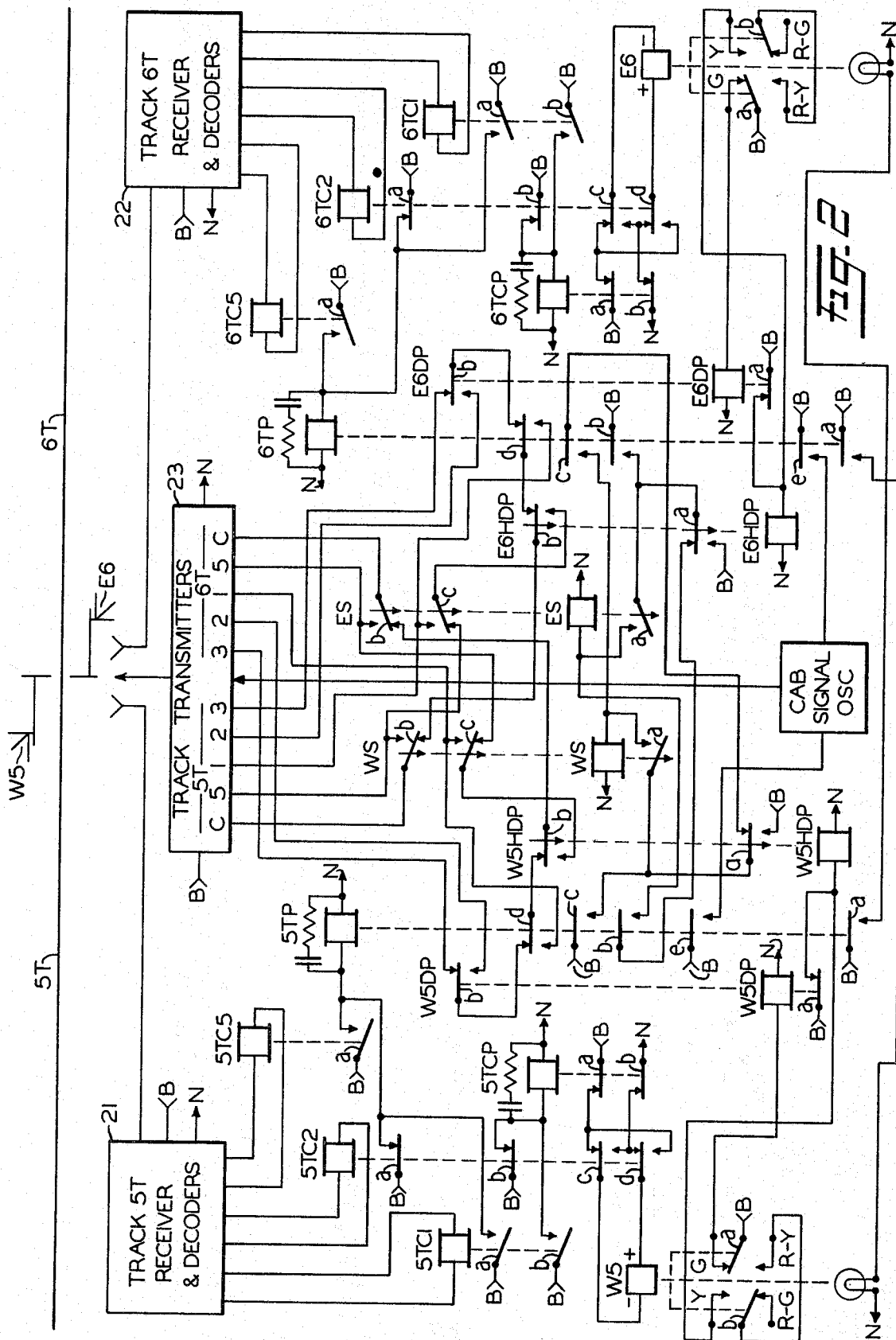


Fig. 1



JOINTLESS CODED TRACK CIRCUITS FOR RAILROAD SIGNAL SYSTEMS

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of our co-pending application Ser. No. 276,066, filed July 28, 1972, and now abandoned. Our invention pertains to jointless track circuits for railroad signal systems. More particularly, this invention relates to coded alternating current track circuits without insulated joints for transmitting a different frequency in each direction in each track section to simultaneously detect train occupancy, transmit signal commands, and establish traffic direction in a signalling system.

Due to rising labor costs, a major disadvantage in prior art signal systems is the need for insulated rail joints to electrically separate the adjoining track sections. Another disadvantage in some types of signal systems is the requirement for line wires extending along the railroad right-of-way between the various signal locations in order to provide additional signal controls. In addition to the initial installation costs for such elements, the maintenance costs of each item after construction are especially burdensome under present economic conditions. Although track circuits without insulated joints are available, generally they are too short in length to be practical for main line railroad signal systems. In order to use jointless type track circuits in signal systems for long stretches of main line, it is necessary from an economic standpoint for the track circuits to be of a reasonable minimum length, at least on the order of 5,000 feet. Such a system using jointless track circuits desirably also requires no wayside line wires between locations except possibly one pair for the supply of central station power to the various locations, unless primary battery is used, for the operation of apparatus and track circuits. A system including these characteristics is of particular advantage and desirable for a signaling system for stretches of track between station locations, especially where welded rail with very few joints is being used.

Accordingly, an object of our invention is an arrangement of long, jointless track circuits for railroad signaling systems.

Another object of the invention is a railroad signaling system using coded jointless track circuits for train detection and signal commands.

Still another object of our invention is an arrangement of jointless track circuits for a stretch of railroad track to detect the presence of trains, to establish the direction of traffic, and to transmit signal commands to wayside and/or cab signal apparatus.

It is also an object of our invention to provide a railroad signal system using jointless, coded alternating current track circuits, each circuit transmitting a different frequency in each direction through the circuit length to detect the presence of trains therein, to determine the direction of approaching trains, and to transmit speed commands to the trains or to wayside apparatus.

A further object of the invention is an arrangement of jointless, coded alternating current track circuits which provide an either-direction signaling system for a stretch of railroad track without line wires between the signal or block locations.

Another object of our invention is a railroad signaling system using alternating current track circuits of rela-

tively low frequency, without insulated joints between track sections, for train detection and coded energy to transmit a plurality of signal commands without the use of wayside line wires.

Further, it is an object of our invention to provide block or track section definition in a signaling system without insulated joints by connecting a low impedance bond across the rails to confine track circuit energy to a given block or section in which it is identified by pickup and receiver devices having a specific association therewith.

Other objects, advantages, and features of our invention will become apparent from the following description when taken with the accompanying drawings and appended claims.

SUMMARY OF THE INVENTION

In practicing our invention, the stretch of railroad track to be signaled is divided into track sections by low impedance cross bonds connected between the rails. However, the adjoining section rails are not insulated from each other by insulated joints. Each cross bond is actually one winding of a track transformer coupling a track transmitter device to the rails. The track transmitter unit, principally a power amplifier, is connected to the other winding of the track transformer and supplies an alternating current of selected frequency to the rails of the sections in each direction from the bond location. Each track transmitter may thus be a standard unit with the selection of the track frequencies accomplished through the use of separate oscillator units, each generating a preselected frequency. Two such oscillators are used at each bond location between adjoining sections. The oscillator output is coded or modulated at a selected rate in accordance with the traffic conditions in advance in the direction for which the oscillator is assigned. The modulated signal is then applied to the track transmitter which, in turn, provides coded track current of each frequency.

Two track receiver units, one for each direction from the cross bond, are provided at each location, each tuned to a specific and different frequency, differing also from those of the associated oscillators. Each track receiver is coupled to the rails by a pair of energy pickup coils placed adjacent to the rails of the corresponding track section in the vicinity of the associated cross bond. These receivers are tuned to respond only to a preselected frequency which is received from an associated track transmitter at the other end of the track section to which the receiver is assigned. Each receiver demodulates the coded alternating current received to produce a code rate output which is applied to decoding units to determine which signal command or traffic condition indication has been received. Through a logic network, the received code rate is effective to select a particular code transmitter which controls the oscillator supplying the track frequency for the other track circuit at that location.

In this manner, coded alternating current of different selected frequencies is supplied at each end of a track section extending between adjacent cross bond locations. Each track section also has two track receivers, one at each end, each tuned to receive only alternating current supplied from the transmitter at the opposite end of the same section. Each receiver demodulates the received track current and outputs a code rate or modulating frequency signal. This output activates or is

passed by the correspondingly tuned decoding unit, each decoding unit of the associated bank detecting one code rate only. The detected code rate, of course, determines the signal indication provided for trains entering that track section in that particular direction while the deenergized condition of a particular track receiver detects the occupancy of the corresponding section by a train. To provide for the transmission of cab signal energy through the rails to the train by the same track transmitter unit, a single frequency is provided by a cab signal oscillator at each location. The code rate is determined by the traffic conditions in advance, depending upon the direction of the train approaching through one of the track sections.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

In describing in greater detail the apparatus embodying our invention, reference will be made to the accompanying drawings in which:

FIG. 1 is a schematic block diagram illustrating the apparatus at one location in a track circuit arrangement embodying our invention.

FIG. 2 is a diagrammatic illustration of the specific details of a logic circuit network usable in the arrangement of FIG. 1.

In each of the drawing figures, similar reference characters designate similar apparatus. At each location, a source of direct current energy is provided for operation of the apparatus. Since the use of any one of several types of such energy sources is conventional, a specific source is not shown. However, connections to the positive and negative terminals of this source are designated by the references B and N, respectively.

Across the top of FIG. 1 is a two-line representation of a portion of railroad track which is part of a stretch of track extending beyond the drawing figure in each direction, for example, extending between two station locations. Connected across the rails at the center of the drawing is one winding of a track transformer 11. This winding is of a relatively low impedance at the alternating current frequencies used in the system. It establishes a dividing point between track sections 5T and 6T shown, respectively, to the left and right of the winding or cross bond connection between the rails. It is emphasized, however, that each rail is electrically continuous from one section to the other, there being no insulated joints associated with the cross bond connection. Similar cross bonds or transformer windings are connected across the rails at the left and the right of the drawing at the opposite ends of sections 5T and 6T, respectively. One form of such a track transformer providing cross bond connections is shown in Letters Patent of the United States No. 3,328,581, issued June 27, 1967, to Crawford E. Staples, for a Rapid Transit Speed Control System. Cross bonds usable in our arrangement, depending on the specific circumstances, are shown in the various parts of FIG. 16 of this patent. The specific showing in FIG. 16c illustrates the use of a center tap from the cross bond connection if the stretch of railroad is electrified. Another cross bond suitable for use in our arrangement is shown in Letters Patent of the United States No. 3,268,843, issued Aug. 23, 1966, to Ralph Popp, for Electric Induction Apparatus For Use In Railway Signal Systems.

Connected to the other winding of track transformer 11 is a track transmitter device, shown by a conven-

tional block, which supplies sufficient energy for the track current of the track circuits of both sections 5T and 6T. Similar transmitters, not actually shown, will be connected across the track transformers at the other end of each track section. The frequency of the alternating current used in the track circuits is established by a separate frequency determining means at each location, shown as a plurality of oscillator units. In other words, each track transmitter is a standard item for the system, is principally a power amplifier for developing sufficient energy level for the track currents, and is dependent upon external means to establish frequency. At this center location in the drawing, associated with the track transmitter, are the F1 and F2 oscillators and a cab signal oscillator. Each of the oscillators for track circuit current, that is, the F1 and F2 oscillators, generates a different preselected frequency selected from a plurality of frequencies F1, F2, F3, etc., designated for the track current. The cab signal oscillator generates a frequency different from any of the plurality of track current frequencies and the same at each location in order to simplify the train-carried cab signal apparatus when used. This last oscillator, of course, is omitted if the trains are not equipped with cab signal apparatus.

Returning to the other oscillators, to avoid interference the frequencies F1 and F2 here used will not be repeated within two or three track sections in succession either way from the location shown. This repetition within some prefixed distance is possible since the cross bonds are designated to shunt nearly all the track current supplied from the other end of that section. The track currents of these two frequencies generated at this center location are obviously transmitted in both directions from track transformer 11 but, as will become apparent, frequency F1 is effective only in section 5T and frequency F2 is effective only in section 6T. This is determined by the tuned receiver units. For example, frequency F3 is supplied at the other end of section 5T, as indicated by the F3 input arrow, and although transmitted in both directions, will be received only at the illustrated center location by the similarly tuned receiver unit, to be described shortly. Likewise track current of frequency F4 is supplied to the rails at the other end of section 6T and is received only by the correspondingly tuned receiver shown at the center location. Each adjacent track circuit in either direction will be supplied with energy of a different pair of track current frequencies.

Each location is provided with two receiver units, each tuned to a different frequency, as illustrated at the center location in FIG. 1 by conventional blocks since such units may be of any conventional design. One track receiver is coupled to the rails on each side of the cross bond connection by a pair of energy pickup coils placed adjacent to the rails. For example, the F3 receiver is coupled to the rails by pickup coils 12 and 13, while receiver F4 is coupled by coils 14 and 15. In each case, one of the pair of coils is placed adjacent to each rail. Energy is induced in each coil by the track current and is similar in frequency and character. Each pair of coils is connected so that the energy induced is totaled and supplied to the associated track receiver.

Each receiver unit is tuned to respond only to track current of the designated frequency which, incidentally, is that transmitted from the other end of the associated section. Thus, the receiver associated with section 5T at the illustrated location is tuned to frequency

F3 which is transmitted from the left end of the section. Correspondingly, a receiver coupled to the rails at the left end of section 5T would be tuned to frequency F1 which is the frequency selected for one current transmitted from the illustrated location. Correspondingly, for section 6T, the illustrated receiver is tuned to frequency F4 while the receiver at the right end would be tuned to frequency F2. Each receiver is thus nonresponsive to track current of any frequency transmitted from the same location or to the second frequency current transmitted in multiple at the far end of the associated section. An output from each receiver, when energized, is applied to a bank of decoding units as will be shortly discussed. It is to be noted that the connections for the couplings of the receiver and track transmitter units to the rails are shown in conventional two-wire symbols, illustrating complete circuits. However, the symbolic connections from the receiver and transmitter units to the remaining apparatus at the illustrated location are in the form of single line flow channels indicating the flow of energy and/or signal indications between the various units. Since all units are shown by conventional blocks and any one of various types of apparatus may be used depending upon the specific system, these flow line connections represent all associated connections and coupling links that are necessary between the illustrated apparatus.

In order to avoid the use of wayside line wires between locations for determining advance traffic conditions and still provide multiple signal indications for controlling train movement, the track current supplied to the rails is coded or modulated at a very low rate or frequency, as compared with the alternating current frequency selected for the track current which carries the code signal. For example, the track current frequencies may be selected in the range of 150-600 Hz although higher or lower frequencies in the audio range are also usable. To a considerable degree, the desired length of the track circuit determines the range of track current frequencies. The code rate or modulating frequency for pulsing or coding the track current for additional signal indications is then, by way of example, selected in the range of 1.25 to 8.0 Hz. These advance traffic condition signals or code rates are generated in any well-known manner. For example, mechanically tuned code transmitters of the relay types known in the prior art may be used or low frequency, solid state type oscillators may be employed. For this reason, the code transmitters or traffic condition signal generators are illustrated in the drawing by conventional blocks only as a bank of five coders positioned in the lower center. It should be understood that any type known in the art or designed for the system may be used. Using five separate code rates, six wayside signal indications, including the stop indication designated by the absence of any code, will be available for train control. Thus, the use of five coders is by way of illustration only and the actual number will be determined by the number of signal indications and other special track current carried indications required. As will be understood by those familiar with railway signaling, even though five code rates may be utilized in a coded system, the generation of all code rates may not be required at each signal or between-section location. Nor will every code rate necessarily be received at each such location.

The pertinent code rate, in accordance with advance traffic conditions and other speed restrictions, is se-

lected by the logic network unit, which will be shortly described, and separately applied to oscillators F1 and F2. The selection for each direction is separate and distinct and need not necessarily result in the same code rate applied to each oscillator. This code selection results in a modulated output from the oscillator so that, in turn, the track transmitter output to the rails is a coded or pulsed track current at the established frequency and selected code rate. A selected code rate from the coders is also applied by the logic unit to the cab signal oscillator. A similar result is obtained in which cab signal energy at the predetermined frequency of the cab signal oscillator and the selected code rate is applied through the track transmitter to the track. The code rate will normally be the same as that otherwise applied to one or the other of the track circuit oscillators as determined by the direction of approach of the detected train.

The logic network unit, shown by conventional block, is the heart or brain of the circuitry at each location. This unit receives the output from each decoder bank and accordingly selects the code rate of the track current supplied to the corresponding approach, i.e., other, section. In other words, the code rate modulating the track current received from section 5T, as detected by the bank of decoders associated with the F3 receiver, determines or selects, through the logic network, the code rate modulating the track current supplied to the approach section 6T. Conversely, the code rate received through section 6T determines the code rate for the track current applied to section 5T. The logic network also, from the received code rates, determines the signal indications to be displayed by any associated wayside signals. Each receiver and the logic unit may also jointly function without the decoders, as an occupancy detection means which detects the absence or presence of a train in the corresponding track section as track current is or is not, respectively, received by that receiver. If approach control is used, the logic unit actuates the cab signal oscillator when track occupancy is determined to supply cab signal current at the proper code rate from the transmitter into the rails and thus to the apparatus on the approaching train.

Since the actual specific circuitry will depend upon the complexity of the signaling system, the logic network in FIG. 1 is shown as a conventional block. Such apparatus and circuitry may be of the relay type or may be a solid state arrangement. Examples of the relay type from the prior art may be found in Letters Patent of the United States No. 2,248,321, issued July 8, 1941, to Earl M. Allen, or No. 2,751,491, issued June 19, 1956, to Thomas W. Tizzard. A form of solid state circuitry, which can be adapted to these logic circuitry requirements, is disclosed in Letters Patent of the United States No. 3,500,388, issued Mar. 10, 1970, to Donald B. Marsh and Walter W. Sanville. A specific relay logic network is shown in FIG. 2 and will be discussed shortly.

Each of the bank of five decoder units shown associated with each receiver F3 and F4 may be LC tuned circuits or may be active filter units. In either case, each is designed to pass only a preselected one of the code rates in use in the signaling system. Thus, the single output flow line from each bank of decoders to the logic unit is actually a multiple path for denoting the code rate selection passed. At any time, the track cur-

rent received by the corresponding receiver will be modulated by only a single code rate so that only a single decoding unit will be active to pass a signal to the logic unit to determine the signal indication to be displayed for that traffic direction and the code rate selected for the approach track section, as previously described. Obviously, when no trains are in the track shown, both banks of decoding units will have one unit active to provide an output into the logic network as track current is received from both directions by the F3 and F4 receivers.

Referring now to FIG. 2, a specific logic circuit network which may be used in the arrangement of FIG. 1 is illustrated. Across the top of this drawing, the same stretch of track is shown by a single line representation with portions of sections of 5T and 6T illustrated. The transformer 11, FIG. 1, with its cross bond connection between the rails is located at the point where signals W5 and E6 are opposite the stretch of track. However, in this drawing, the track transformer and cross bond connection are not specifically shown. The wayside signals shown by conventional symbol control the movement of trains into the correspondingly numbered track sections, e.g., signal W5 controls movement into section 5T. At the upper left and right of this drawing are conventional blocks 21 and 22 which, respectively, designate the track receiver and decoding unit combinations associated with track sections 5T and 6T. The track couplings for the receiver units are schematically shown by flow lines as originating at the wayside signal location and are the same as shown in FIG. 1. Although the details are not specifically shown, when the track current energy is coupled to the receiver unit and thus to the decoders, operating energy from terminals B and N of the direct current source is supplied to one of the decoding relays TC associated with the unit selected in accordance with the code rate modulating the received track current. For example, if the F3 frequency track current flowing through section 5T and thus coupled to block 21 is modulated by track code 1, relay 5TC1 will be energized. Only three code rates 1, 2, and 5 are assumed as being received by either of the track receiver units at this location although all five code rates are utilized in the total system of which this location is a part. Further, only four code rates are generated and transmitted from the illustrated location since this is sufficient to illustrate the concept of operation of the system of our invention.

Track occupancy for the illustrated sections is recorded by the track repeater relays 5TP and 6TP, respectively. It will be noted, for example, that relay 5TP is energized by a circuit which includes in multiple front contacts *a* of each of the decoding relays 5TC1, 5TC2, and 5TC5 associated with receiver-decoder block 21. In the at-rest condition assumed or illustrated in FIG. 2, that is, with no trains in the stretch, relay 5TC2 is energized by the decoders and thus relay 5TP is energized and picked up. It will be noted that relay 5TC5 is used for no other purpose than to energize relay 5TP. Thus the code rate 5 provides track occupancy detection and, as will become apparent later, is used under special conditions when traffic direction has been established through this stretch of track. Under these conditions, relay 5TC5 will release as soon as train occupies section 5T and thus will detect the presence of an approaching train. To further detect when code rates 1 or 2 are being received, each loca-

tion is provided with code rate repeater relays such as relay 5TCP associated with unit 21. Relay 5TCP is energized by a simple circuit including, in multiple, front contacts *b* of relays 5TC1 and 5TC2 and thus is energized and picks up when either of these code rates is received at this location through section 5T. If code rates 3 and 4 were also received at suitable times by receiver and decoder unit 21, relay 5TCP, or a similar auxiliary relay, could be used to detect the reception of these codes also. It will be noted that the track repeater and code repeater relays are each snubbed by a series capacitor-resistor arrangement connected in multiple with the relay winding to provide a brief slow release period to bridge possible open circuit times as the decoding relays change positions during the change of code rate.

The wayside signals are assumed to be of the searchlight type, for the convenience of explanation, although this is not critical to the system of our invention. The signal mechanisms, including operating windings, position repeater contacts, and lamps are shown in the lower left and right for signals W5 and E6, respectively. Such signal mechanisms have a biased winding as designated by the positive and negative symbols placed adjacent to the winding representation. It will be understood that, when operating energy is applied with a polarity in accordance with these biasing symbols, the roundel structure is operated to provide a yellow aspect or an approach indication. Conversely, when reverse polarity energy is applied to the signal operating winding, the roundel structure is moved to provide a green aspect or a clear indication. When the winding is deenergized, that is, no operating energy applied, the roundel structure is biased to its red aspect position to provide a stop indication to approaching trains.

The operating winding also controls the contact structure to repeat the position of the signal mechanism. Each contact structure, shown directly below the winding symbol, has a contact *a* which closes in its upper or front position when the green aspect is displayed, as shown by the letter G placed adjacent the front contact. The associated contact *b* is closed in its upper position only when the signal is displaying a yellow indication, as represented by the letter Y adjacent the upper contact. Contact *a* closes in its lower or back position when the signal displays either a red or yellow indication and contact *b* closes in its back position when the signal is displaying either a red or a green indication. Since an at-rest condition for the apparatus is assumed, each signal is illustrated as displaying a green aspect and contacts *a* and *b* of each signal are shown in the position which they occupy under these conditions. Each signal lamp is approached energized and is controlled by a back contact of the opposite track repeater relay. For specific example, when relay 6TP releases on the approach of a train in section 6T, it completes the circuit over its back contact *a* for energizing the lamp of signal W5. Correspondingly, the circuit for the lamp of signal E6 includes back contact *a* of relay 5TP. The signal lamps are shown as energized by the local source of direct current energy but if desired, a low voltage alternating current supply may be provided for the signal lamps.

The position of each signal is repeated by a pair of position repeating relays which are controlled over circuits controlled by the contact structure of the signal. For example, in the conditions assumed, a distant re-

peater relay W5DP is energized by a simple circuit between terminals B and N which includes front or green contact *a* of signal W5 and the relay winding. The corresponding distant repeater relay E6DP is similarly energized over front contact *a* of signal E6. A home and distant repeater relay is associated with each signal and is energized over either of two multiple circuits. For example, relay W5HDP is energized, under the condition shown, by a simple circuit including front contact *a* of relay W5DP. Alternately, relay W5HDP may be energized when signal W5 is displaying a yellow indication over a circuit including back contact *a* and front contact *b* of the signal contact structure of signal W5. A similar circuit network controls relay E6HDP.

The center block in FIG. 2, designated 23, represents the track transmitter, the track current oscillators, and the coders of FIG. 1 and is shown in this simplified manner for convenience of illustration. Across the bottom of block 23 are two sets of terminals associated respectively with track sections 5T and 6T, as indicated by the overlined symbol. These terminals are used in connection with the selection of the code rate to be applied to the corresponding track section. The terminal C is a common terminal from which a circuit must be completed to one of the numbered terminals to select the desired code rate. The numbered terminals 1, 2, 3, and 5 represent the correspondingly numbered code rate and provide a selection for the transmission of such a code rate modulated on the track current of frequencies F1 or F2, respectively.

The selection of code rates involves, in addition to track conditions, the directional stick relays ES and WS, the first being for eastbound direction and the latter for the westbound direction. Conventionally, these directions designate trains moving to the right and, conversely, to the left through the stretch of track shown. These directional stick relays are used in order to set up conditions to allow a following train movement and are energized when a train moving in the corresponding direction passes this signal location. For example, relay ES is initially energized when an eastbound train passes signal E6 by a circuit which includes back contact *b* of relay 6TP, front contact *a* of relay E6HDP, and back contact *b* of relay 5TP. Relay ES has two stick circuits, the primary including back contact *b* of relay 6TP and front contact *a* and the winding of relay ES. An alternate stick circuit includes back contact *a* of relay E6HDP and front contact *a* of relay ES. It is to be further noted that both relays ES and WS have inherent slow release characteristics, as designated by the downward pointing arrow drawn through the movable portion of each contact of these relays. Such relays, when deenergized, retain front contacts closed for a predetermined slow release period of time. This characteristic is utilized here to allow the relays to remain picked up during the transfer between pickup circuits and stick circuits under certain conditions. It is also to be noted that the home and distant repeater relays HDP for each signal also include inherent slow release characteristics.

In considering the circuits for the logic network for selecting the code rate to be applied to the track section, it will be sufficient to describe only those associated with track section 5T as similar circuit arrangements for 6T will become obvious with an understanding of the 5T circuits. A first and simple circuit for selecting code rate 5, when such is appropriate, extend-

ing between terminals C and 5 of the 5T side of track transmitter block 23, includes front contact *b* of relay WS. An alternate circuit for selecting code 5 extends between the same two terminals over back contact *b* of relay WS, back contact *b* of relay E6HDP, and back contact *c* of relay ES. One circuit for selecting code rate 1 for section 5T extending between terminals 1 and C of this portion of block 23 includes back contact *d* of relay 6TP, front contact *b* of relay E6HDP, and back contact *b* of relay WS. Another, more normal circuit for selection of code rate 1 includes front contact *c* of relay ES, back contact *b* of relay ES, back contact *b* of relay E6HDP, and back contact *b* of relay WS. This latter circuit is used to select code rate 1 when a train is receding from the signal location through section 6T.

When a train receding in the eastbound direction from the signal location has cleared section 6T, the circuit for the selection of code rate 2 for application to track section 5T extends between terminals 2 and C of that portion of block 23 over back contact *b* of relay E6DP, front contact *d* of relay 6TP, front contact *b* of relay E6HDP, and back contact *b* of relay WS. Under conditions when no train is in the stretch of track and traffic direction is not established, code rate 3 is normally transmitted in both directions from the signal location shown. A typical circuit for section 5T extends from terminal 3 of that part of block 23 over front contact *b* of relay E6DP, front contact *d* of relay 6TP, front contact *b* of relay E6HDP, and back contact *b* of relay WS to terminal C. This is the circuit which is closed under the at-rest condition illustrated in FIG. 2.

We shall now describe the operation of the apparatus when an eastbound train moves through section 5T and 6T. From FIG. 1, track current at frequencies F1 and F2 is supplied through track transformer 11 to the rails and, with no train in either section, flows through the rails to the receivers at the opposite ends of sections 5T and 6T. The bonds across the rails at the far end of these sections, as described, have a relatively low impedance at the alternating current frequencies used in the system so that little, if any, of the track currents of frequencies F1 and F2 flows in the rails beyond the other ends of sections 5T and 6T. At the same time, track currents of frequencies F3 and F4 are received at the location shown through, respectively, the rails of sections 5T and 6T from the track transmitters at the other end of each of these sections. Once again, the cross bond winding of transformer 11 is of relatively low impedance so that practically all of these currents flow through this winding and do not appear in any substantial amount in the other section. This flow of current in sections 5T and 6T, through pickup coils 12, 13 and 14, 15, activates receivers F3 and F4 which are tuned to these frequencies. The energy received is demodulated and applied to the associated bank of decoders which determine which code rate has been received and pass a corresponding indication to the logic network. Normally, with no train in either section, the cab signal oscillator is not activated by the logic unit which determines that no train is approaching its location and that there is thus no need for the cab signal current.

We shall assume initially that traffic conditions are still such that code rate 2 is received through the track current flowing in both sections at the location shown in FIG. 2. Under these conditions, each signal W5 and E6 displays a green or clear indication, since the associ-

ated TCP and TC2 relays are picked up to apply a reverse polarity to each signal winding. Under such normal conditions, the track current transmitted in each direction is modulated by code rate 3. In other words, the track currents of frequencies F1 and F2 transmitted from this location are modulated by code rate 3 for transmission of signal information to adjacent locations. This operation is controlled or exists since both track repeater relays are energized and picked up and both signal repeater relays for each wayside signal are likewise picked up. Thus for both sides of track transmitter block 23, a circuit is closed between terminals C and 3 to actuate transmission of that code rate. As will become apparent later, under this at-rest condition both directional stick relays are in their released positions.

Some time prior to the assumed eastbound train entering track section 5T, the code rate modulating the track current of frequency F3 received through the rails of section 5T changes to code rate 1. This causes relay 5TC2 to release and energizes 5TC1. Although relay 5TCP remains energized and retains its front contacts *a* and *b* closed, the shift of contacts *c* and *d* of relay 5TC2 from front to back changes the polarity on the winding of signal W5 and this signal, now being energized by normal polarity, shifts to a yellow or approach indication. Since the corresponding change in the contacts of signal W5 causes relay W5DP to release, but holds relay W5HDP, the circuit for selecting a code rate for track current of frequency F2 being transmitted through section 6T now shifts from terminal 3 to terminal 2, being transferred by contact *b* of relay W5DP. In an alternate form of operation with a traffic direction setup, when a train enters or traffic is established through the stretch of track including sections 5T and 6T, the track code modulating all track currents flowing in the eastbound direction is shifted to code rate 5. Under these conditions, at the location in FIG. 2, relay 5TC2 releases and relay 5TC5 picks up. Thus relay 5TCP releases, interrupting the energy supply to the winding of signal W5, but relay 5TP remains energized over front contact *a* of relay 5TC5. Signal W5 moves to its red position and both signal repeater relays release since there is no circuit for holding either relay energized. At the same time, a shift in the logic circuit network occurs to institute the transmission of code rate 5 modulated onto the F2 track current flowing through section 6T. The circuit between terminals 5 and C of the 6T side of block 23 under these conditions includes back contact *b* of relay ES, back contact *b* of relay W5HDP, and back contact *c* of relay WS. This last described type of operation would occur in CTC or APB territory and is conventional for such type of signal systems. The shift to code 5 transmitted in the direction of the train movement occurs at least when the train enters the overall stretch of track between adjacent stations.

When the train moving from left to right through the stretch enters section 5T, its wheels and axles shunt the flow of track current of frequency F3 so that energy is no longer picked up by coils 12 and 13 for application to the F3 receiver. With a deenergized receiver F3, the decoder combination of block 21 produces no output and all of the associated decoding relays TC release to cause the logic circuitry to register the occupancy of section 5T by this train. Specifically, relays 5TP and 5TCP release to register this track occupancy. The

opening of front contacts *a* and *b* of relay 5TCP, if not previously released, deenergizes the winding of signal W5 at this time and the signal moves to its red indication. The closing of back contact *e* of relay 5TP energizes the cab signal oscillator to provide a cab signal current for pick up by the train apparatus if such equipment is in use. The cab signal frequency is applied to the track transmitter block 23 and the code rate selected to modulate this current within unit 23 depends upon the code rate being received by the F4 receiver from track section 6T. Normally the cab signal code rate selected for section 5T is the same as applied to the F1 oscillator prior to the time the train entered section 5T. However, the rate selected may also be different depending upon the train control requirements built into the logic circuit network. Obviously, from FIG. 1, the cab signal current will also flow into section 6T where, since no train is present, it has no effect on any apparatus or operations.

As specifically shown in FIG. 2, with the absence of any track current received through section 5T to indicate the presence of a train therein, the logic network selects a code rate for oscillator F2 which reflects the fact that the immediate section in advance is occupied by a train. The actual circuit extends from terminal C in the 6T part of block 23 over back contact *b* of relay ES, back contact *b* of relay W5HDP, and back contact *c* of relay WS to terminal 5 so that code rate 5 is selected. Of course, as previously described, the overall signal system may be so designed that, when the traffic direction is established from left to right, code rate 5 immediately modulates the track currents supplied from left to right throughout the stretch, including section 6T, thus blocking the opposite direction of train movements.

When the train passes the location shown in the drawings, the track current supplied through the rails of section 6T from the opposite end is shunted away from pickup coils 14 and 15 which supply energy to the F4 receiver. With receiver F4 thus deenergized, no demodulated code rate is provided to the associated bank of decoders and relay 6TC2 releases. Since the other decoding relays are already released, relay 6TP and 6TCP also release and the logic network registers the occupancy of section 6T by the train. With front contacts *a* and *b* of relay 6TCP open, the winding of signal E6 is deenergized and the signal moves to its red indication so that both its front contacts open and the associated signal position repeater relays also release. When relay 6TP releases, the circuit is completed for energizing direction relay ES, including back contact *b* of relay 6TP, front contact *a* of relay E6HDP which remains closed for the release period of this relay, and back contact *b* of relay 5TP. The closing of front contact *a* of relay ES as this relay picks up completes its stick circuit further including back contact *b* of relay 6TP. The subsequent closing of back contact *a* of relay E6HDP completes a multiple connection to terminal B for this stick circuit.

When this train clears section 5T and moves on to the right, the F3 receiver is again activated since track current now flows from the opposite end of section 5T and is picked up by coils 12 and 13 to energize the receiver. Assuming that at least track code rate 5 is received with traffic still established in the eastbound direction, relay 5TC5 is energized and picks up to close its front contact *a* to also energize track relay repeater 5TP. The

logic network thus registers the clearing or the non-occupancy of section 5T and also selects a code rate for transmission through section 5T reflecting the traffic condition in advance, that is, that section 6T is occupied with relay ES held in its energized position. The circuit is completed for the 5T side of transmitter block 23 from terminal C over back contact *b* of relay WS, back contact *b* of relay E6HDP, and front contact *c* of relay ES to terminal 1. Thus the lowest proceed signal code rate, i.e., code rate 1, is applied to modulate the output of the F1 oscillator and produces a track current of frequency F1 coded at this rate. The F2 oscillator continues to be modulated by code rate 5 since front contact *b* of relay ES is closed to complete circuit between terminals 5 and C of this part of transmitter block 23. Thus the code rate applied by the logic network to the F2 oscillator will continue to reflect that traffic direction is established from left to right. However, the application of track current of frequency F2 to the rails of section 6T will have no immediate effect until the section rails are no longer shunted by the train moving through that section. Since the direction from left to right was previously established as the train approached the location, the cab signal oscillator may or may not be activated while the train is receding through section 6T even though back contact *e* of relay 6TP is closed. This is a matter of logic circuit design and depends upon the operation desired and the periods during which the cab signal current is to be supplied.

When this train clears section 6T, track current of frequency F4 is again received through pick up coils 14 and 15 to energize the F4 receiver. Similar to the previous discussion concerning the illustrated location when the train cleared section 5T, the code rate modulating the F4 track current therefore is the lowest proceed code rate or code rate 1 since only one track section is clear. Relay 6TC1 is thus energized at this time by the track receiver, decoder combination 22 and, with the closing of its front contacts *a* and *b*, in turn energizes relays 6TP and 6TCP, respectively. With relay 6TC2 released, the winding of signal E6 is energized now with normal polarity and signal E6 moves to its yellow or approach indication. Relay E6HDP is picked up by the closing of front contact *b* of signal E6 while back contact *a* is closed. With relay 6TP picked up to indicate that section 6T is clear, the logic circuitry now recognizes that a different advanced traffic condition exists and accordingly selects a higher speed code rate for the F1 oscillator to modulate the track current being supplied to section 5T. It will be further noted that, with relays 6TP and E6HDP picked up, their back contacts *b* and *a* are open to interrupt the stick circuits for relay ES which shortly releases. The code rate 2 is now selected for modulating the track current supplied to section 5T, a circuit existing from terminal C of the 5T side of block 23 over back contact *b* of relay WS, front contact *b* of relay E6HDP, front contact *d* of relay 6TP, and back contact *b* of relay E6DP to terminal 2. It will be noted that, with front contact *c* of relay ES and back contact *d* of 6TP open, both circuits for selecting code rate 1 in this side of block 23 are interrupted.

When this eastbound train eventually moves on far enough that track current F4 in section 6T is modulated by code rate 2, unit 22 causes relay 6TC2 to pick up and relay 6TC1 to release. Relays 6TP and 6TCP remain energized and, with their windings snubbed, do

not open front contacts during the shift in energizing circuits. The closing of front contacts *c* and *d* of relay 6TC2 reverses the polarity of the energy applied to signal winding E6 and the signal moves to its green position. Relay E6DP together with relay E6HDP are now energized. The shifting of contact *b* of relay E6DP from back to front transfers the code rate selection for section 5T from 2 to 3. If the location at the left end of section 5T is a station location, the reception of code rate 3 modulated onto F1 track current may be used, for example, to register the stretch of track clear to the next station east and allow a change of established traffic direction.

Obviously, the operation under the situation of a train moving from right to left through the track sections shown will be similar but of opposite sequence to that just described. It is therefore not necessary to complete a detailed description of this operation as it may be developed by those skilled in the art when considered with the previous description and the accompanying drawings.

The arrangement of our invention thus provides a signal system using coded a.c. track circuits without insulated joints. The use of different frequencies in adjacent track sections maintains the separate system functions of detecting track occupancy by section and transmitting signal commands section-by-section in accordance with the advance traffic conditions. The use of coded track current also allows the elimination of wayside line wires between signal locations and yet provides additional signal indications in accordance with the different code rates. Maintenance costs of the system are reduced with the elimination of the insulated joints and the wayside line wires. Our inventive arrangement results, therefore, in an efficient and economical railroad signal system.

Although we have herein shown and described but one arrangement of alternating current track circuits without insulated joints for providing a railroad signal system, various changes and modifications therein may be made within the scope of the appended claims without departing from the spirit and scope of our invention.

Having thus described the invention, what we claim as new and desire to secure by the Letters Patent, is:

1. A track circuit arrangement for a stretch of railroad track having electrically continuous rails, comprising in combination,
 - a. a low alternating current impedance cross bond connected across the rails at selected locations for dividing said stretch into a series of track sections,
 - b. a track current transmitter means at each location coupled to the corresponding cross bond and operable for supplying track current to the section in each direction from the associated bond,
 1. each section current having a different preselected frequency and different from the preselected frequencies of a prefixed number of successive sections in each direction from that particular location,
 - c. a frequency determining means at each location coupled to the associated transmitter means for establishing the preselected frequency of the track current supplied to each section adjoining that location,
 - d. a separate tuned track receiver coupled to the rails on each side of the cross bond connections at each

location and responsive only to track current from the transmitter means at the other end of the corresponding section for producing an output signal,

- e. a single logic network means at each location connected to receive the output signal of each track receiver and responsive thereto for registering a nonoccupied indication of the corresponding section when the signal is present and an occupied indication when the signal is absent,
 - f. a plurality of traffic condition signal generators at each location, each producing a distinct signal representing a predetermined advance traffic condition along the stretch of track, and
 - g. a plurality of decoder units, one for each advance traffic condition signal, associated at each location with each track receiver and coupled to said logic network means,
 - h. said signal generators selectively coupled by said logic network means to said frequency determining means for separately modulating the track current supplied to each adjoining track section in accordance with the detected advance traffic condition in the corresponding direction along said stretch,
 - i. each track receiver further operable for demodulating the received track current to which it is responsive to produce a traffic condition output signal corresponding to the modulating signal selected at the next adjacent location in that direction,
 - j. each plurality of decoder units connected for receiving the output signal from the associated track receiver and responsive thereto for actuating said logic network means to selectively couple a signal generator to modulate the track current supplied to the other track section in accordance with the detected advance traffic condition.
2. A track circuit arrangement as defined in claim 1 in which said frequency determining means at each location includes,
- a. a separate oscillator unit for each track section operable to provide an output signal of a preselected frequency different from the signal frequency of the associated oscillator unit and of each oscillator unit at said prefixed number of successive locations,
 - b. said oscillator units connected to apply the output signals to said track transmitter means for jointly establishing the track current frequency supplied to the rails at the preselected frequency for each section.
3. A track circuit arrangement as defined in claim 2 which further includes at each location,
- another oscillator unit controlled by said logic means to provide a distinct cab signal frequency, the same at each location, when an approaching train is detected occupying either adjoining section and connected to said track transmitter means for also supplying a track current to said rails having said cab signal frequency.
4. A track circuit arrangement as defined in claim 3 in which the plurality of traffic condition generators at each location comprises,
- a. a plurality of code transmitters, each producing distinctive code rate signals representing a different predetermined advance traffic condition along the stretch of track,
 - b. said code transmitters selectively coupled by said logic network means to said oscillator units for sep-

- arately coding the track current supplied to each adjoining track section at that location in accordance with the detected advance traffic condition in the corresponding direction along said stretch,
 - c. each track receiver further operable for demodulating the received coded track current to which it is responsive to produce output signals at a code rate corresponding to the code rate signal supplied at the other end of the corresponding section,
 - d. each plurality of decoder units connected for receiving the code rate output signals from the associated track receiver and responsive thereto for actuating said logic network means to selectively couple a code transmitter to code the track current supplied to the other track section in accordance with the detected advance traffic condition.
5. A track circuit arrangement as defined in claim 4 which further includes at least at selected locations,
- a. a pair of wayside signals, each operable for controlling train movement in one direction past the corresponding location,
 - b. each signal controlled by the associated logic network for displaying to an approaching train a speed command signal indication selected in accordance with the advance traffic conditions detected for the corresponding direction.
6. A track circuit arrangement as defined in claim 5 which further includes,
- a. a pair of energy pickup coils associated with each track receiver and positioned one coil in inductive relationship with each rail of the corresponding section in the vicinity of said cross bond connections,
 - b. each pair of coils connected for supplying to the associated receiver the energy induced in said coils by the track currents flowing in the section rails.
7. A track circuit arrangement as defined in claim 6 in which, at each location,
- a. said low impedance cross bond is the secondary winding of a track transformer which also has a primary winding,
 - b. said track current transmitter means is connected to the primary winding of said track transformer to supply the track currents to said rails.
8. In a track circuit arrangement for a stretch of railroad track having electrically continuous rails, at each of selected locations, the combination comprising,
- a. a track transformer including a first winding and a second low alternating current impedance winding connected across the rails of said track at the selected location to divide said stretch into successive sections,
 - b. a track current transmitter connected to said first winding of the associated transformer for supplying alternating current energy to the rails of each section adjoining that location,
 - c. a frequency determining means connected to the associated transmitter for establishing a different predetermined frequency for the alternating current supplied to the rails of each adjoining section, each frequency determining means also having frequencies different than those at a preset number of successive locations in each direction from that location,
 - d. a separate receiver means coupled to the rails on each side of the second transformer winding rail connections at that location and tuned to a prede-

terminated frequency for receiving only current of a frequency transmitted from the other end of the corresponding section,

- e. a plurality of coding devices, each operable for producing a distinct advance traffic condition code signal for at times modulating the track current supplied to the rails of each section, 5
 - f. a separate plurality of decoding units coupled to each receiver means, each decoding unit responsive only to a predetermined one of the plurality of traffic condition code signals, 10
 - g. each receiver means responsive to the received code signal carried by current for developing a traffic condition code signal output in accordance with the modulation by the received track current and connected for applying the output signal to the associated decoding units, and 15
 - h. a logic network means controlled by both associated pluralities of decoding units for detecting the occupancy condition of each adjoining section in accordance with the receipt or nonreceipt of a traffic condition code signal from each section by the corresponding receiver means, 20
 - i. said devices coupled to said frequency determining means by said logic network means for selectively modulating each track current with a code signal predetermined in accordance with the advance traffic condition code signal received from the decoding units associated with the other track section receiver means. 25
9. A track circuit arrangement as defined in claim 8 in which each frequency determining means comprises, 30
- a. a separate oscillator unit for each track section adjoining that location, operable to provide an output signal frequency of the associated oscillator unit and of each oscillator unit at said preset number of successive locations, 35
 - b. said oscillator units at a location controlled by the coding devices selectively coupled thereto by the associated logic means and connected to said track transmitter means for jointly establishing the predetermined frequency and the modulating code signal for the track current supplied to the rails of each section. 40
10. A track circuit arrangement as defined in claim 45

9 which further includes at each location,

another oscillator unit controlled by said logic network means to provide a distinct cab signal frequency, the same at each location, when an approaching train is detected occupying either adjoining section and connected to said track transmitter means for also supplying a code modulated track current to said rails having said cab signal frequency.

11. A track circuit arrangement as defined in claim 10 in which,

- a. each low impedance second transformer winding terminates the modulated track current supplied from the track transmitter at each adjacent location, and which each location further includes,
- b. a pair of pickup coils inductively coupled to the rails on each side of the second transformer winding, one coil of each pair positioned in inductive relationship adjacent each rail in the vicinity of the associated second winding rail connections, 20

- c. each pair of coils connected for supplying to the corresponding receiver means the energy induced in said coils by the modulated track currents flowing in the section rails,

- 1. said corresponding receiver means being responsive only to the induced energy having the frequency to which that receiver is tuned,

- 2. said corresponding receiver means further responsive to any interruption of the rail connections of the second transformer winding at the corresponding adjacent location for actuating the associated logic network means to register a track occupied condition for that section. 30

12. A track circuit arrangement as defined in claim 11, in which each location further includes,

- a. a pair of wayside signals, each operable for controlling train movement in one direction past the corresponding location,

- b. each signal controlled by the associated logic network for displaying to an approaching train a speed command signal indication selected in accordance with the advance traffic conditions detected for the corresponding direction. 45

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,868,075
DATED : February 25, 1975
INVENTOR(S) : Frank V. Blazek & Thomas C. Vaughn

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 17, line 13, erase "code signal carried by" and
insert --track--

line 15, after "modulation" erase "by" and
insert --code signal carried by--

line 24, before "devices" insert --coding--

line 35, after "signal" insert --of a predetermined--

same line, after "frequency" insert --different
from the signal frequency--

line 40, before "means" insert --network--

Signed and Sealed this

Fourth Day of January 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks