

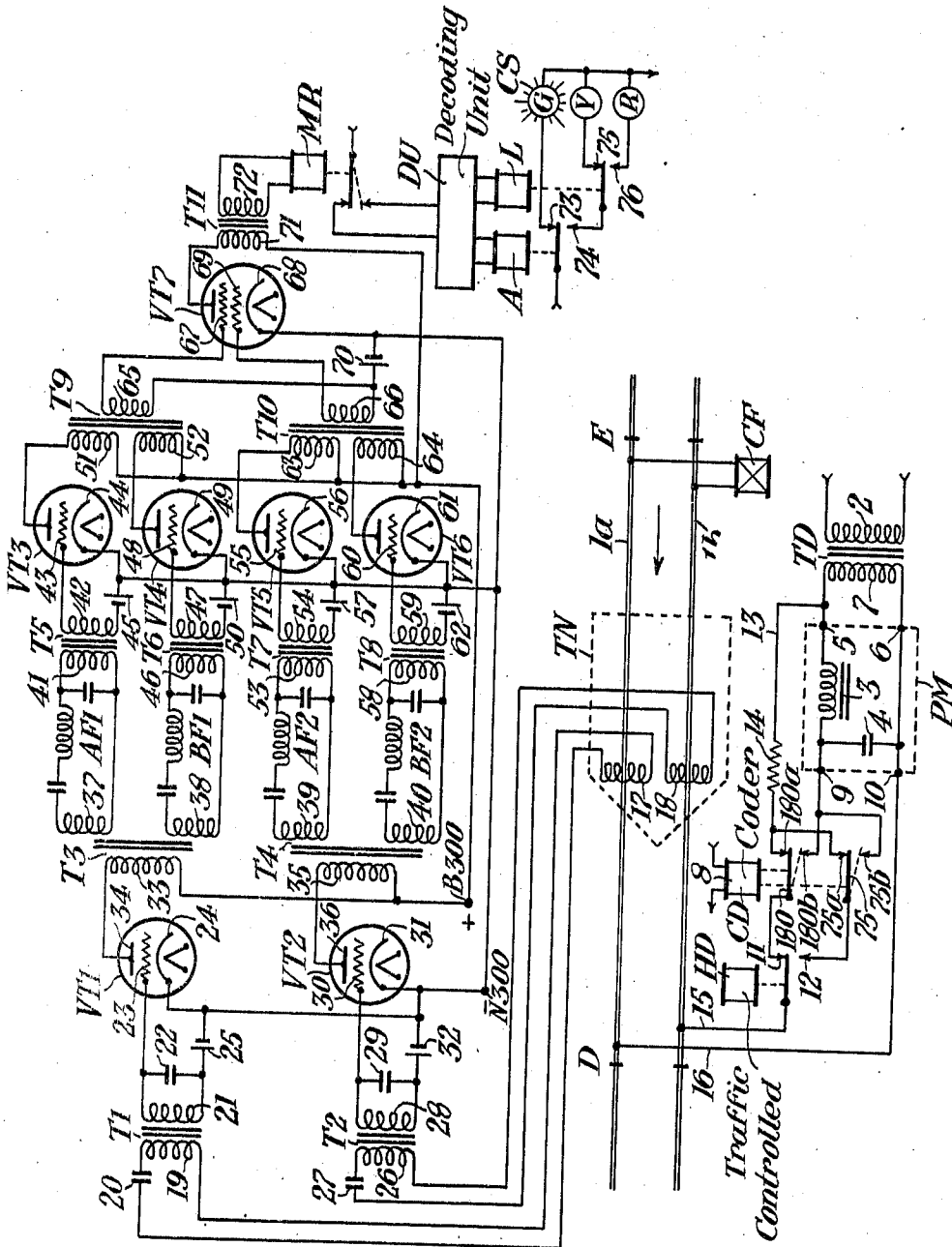
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SIGNAL SYSTEM USING PHASE MODULATION

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SIGNAL SYSTEM USING PHASE
MODULATION

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My invention relates to signal systems using phase modulation, and more particularly to railway train signal systems using phase modulation.

Many signal systems use energy that is coded by periodically interrupting the circuit according to a desired code. For example, certain types of code cab signal systems for railway trains use alternating current that is coded at any one of several different codes by interrupting the circuit at any one of several different rates, such as 180, 120 and 75 times per minute. That is, time is divided into successive code cycles each of which consists of an "on" period during which current flows and an "off" period during which no current flows, these two code periods being preferably of substantially equal durations. Broadly speaking, such coding of alternating current is amplitude modulation of the current, 100 per cent modulation being effected. Such coded current is supplied to a control circuit at one point for actuating receiving apparatus including a decoder coupled to the circuit at some remote point, the decoder in turn governing a signal device in accordance with the code transmitted. In a railway train cab signal system, the control circuit is a track circuit including the rails and train carried receiving apparatus has its input side coupled to the rails and is energized in response to the electromotive force picked up from the rails due to the coded current flowing therein, such receiving apparatus including decoding means responsive to the different code rates of such received electromotive force for selectively governing the position of a multiple position cab signal or other train control device.

One of the limiting factors which determine the amount of power that must be supplied to a control circuit for operating a signal is the amount of interference. Again referring to present day railway train code signal systems, a limiting factor which determines the smallest wayside power that can be used to operate a cab signal over a given length of track is the amount of stray magnetic fields created by outside circuits in the vicinity of the track, and by the so-called "magnetized spots" in the rails. It has been found that such interference in a cab signal system is more pronounced when the control or carrier current is of a low frequency. On the other hand, the attenuation caused by the track rails increases when alternating current of a relatively high frequency is used, and furthermore, the degree of broken rail protection becomes less as

the frequency of the control current is increased. The problem of broken rail protection sets an upper limit of about 20 cycles per second for the control current if relatively long track circuits of the order of 11,000 feet are to be used, such long track circuits being desirable because of the present day high train speeds. Since energy is picked up inductively, the current level must be raised for effective operation of the usual train carried receiving apparatus when current of a frequency low enough to insure ample broken rail protection is used, and thus any power saving must come about through reducing the effects of the interference caused by stray magnetic fields. Power saving is desirable because in many cases the alternating current is obtained from a battery and a tuned vibrator.

Phase modulation has the advantage over amplitude modulation in that a power gain at the transmitter is obtained. That is, for a given transmitter, the power supplied to the control circuit is increased when phase modulation rather than amplitude modulation is used. Experience of investigators in the radio field indicates that with phase modulation a four to one advantage in the power handling capacity of the transmitter is obtained. It has also been found that in equal carrier noise ratios, the peak signal noise ratios obtained by phase and amplitude modulations are about equal. Hence a gain in power obtained by phase modulation results in better overcoming the usual interference.

A wave is phase modulated when its instantaneous phase is deviated from the position it would have taken if the modulation were not present. Such phase shift may be introduced, for example, by passing the wave through a circuit element or network which imparts a time delay to the wave so that the wave at the output of the network has a phase which is different from that at the input.

In view of these circumstances in signal systems, a feature of my invention is the provision of a novel and improved organization of apparatus for a signal system using phase modulation.

Another feature of my invention is the provision of a novel and improved organization of apparatus for railway train cab signal systems using phase modulation.

Still another feature of my invention is the provision of improved apparatus for railway train cab signal systems wherewith saving of power at the transmitter is obtained, better

broken rail protection is assured, and interference by stray magnetic fields is reduced.

Other objects and advantages of my invention will appear as the specification progresses, after which the features, objects and advantages of my invention will be particularly pointed out in appended claims.

The above features, objects and advantages of my invention I attain by providing transmitting apparatus that comprises a source of carrier current, a phase modulating element and a coding device. Such coding device is actuated in a cyclic operation which is divided into two substantially equal periods, a first contact being closed during the first period of each cycle, and a second contact being closed during the second period of each cycle. The source of current is connected to the control or transmitting circuit over two alternative circuit paths. One such path includes the first contact of the coding device but nothing that will shift the phase of the current as supplied by the current source. The other circuit path includes the second contact of the coding device and the phase modulating element which element acts to shift the phase a predetermined degree. Thus during the first code period of each code cycle non-modulated carrier current is supplied to the control circuit, and during each second code period of each code cycle, phase modulated carrier current is supplied to the control circuit. Preferably, a plurality of such coding devices are provided, each of which is actuated at a particular cycle. In other words, each coding device is operated at the particular code rate. A multiple position control means selects the particular coding device that is to be effective.

The receiving apparatus includes receiving means coupled to the control circuit to receive an electromotive force of a frequency, phase modulation and code corresponding to that of the current supplied by the transmitting apparatus. The receiving means is preferably connected to an amplifier to amplify the received energy, but if the received energy is of relatively high energy level such amplifier may not be required. A phase demodulator is connected to the receiving means or to the output of the amplifier, if used, such demodulator being effective to provide at its output an electromotive force which is varied in accordance to the code rate of the received energy. This output electromotive force of the demodulator is used to operate a code following relay, such relay being operated at a rate corresponding to the code rate of the received energy. The code following relay governs the supply of current to a decoding means selectively responsive to the code rate or frequency of the current impulses supplied thereto, and such decoding means in turn governs a multiple position signal device so that the position of the signal device is made to correspond to the code rate of the transmitted energy.

As an aid to the understanding of my invention reference may be had to the accompanying drawing which is a diagrammatic view showing one form of apparatus embodying my invention when used for a code cab signal system for a railway train. It is to be understood that I do not limit my invention to cab signal systems for railway trains and this one application serves to illustrate the many places where such apparatus is useful and at the same time serves to show the peculiar utility of such apparatus when used for control of a railway train cab signal.

Referring to the drawing, the reference characters 1a and 1b designate the track rails of a stretch of railway over which traffic normally moves in the direction indicated by an arrow, and which rails are formed by the usual insulated rail joints with a track section D—E, and which section may be one section of a series of consecutive sections of a signal system. The track section D—E may be of any suitable length as required. For example, section D—E may be a relatively long section of the order of 11,000 feet, which length of track section is desirable where present day high train speeds prevail.

The section D—E is provided with a track circuit which includes a source of current connected across the rails at one end of the section and a track relay connected across the rails at the other end of the section. The means for supplying current to the track circuit of section D—E comprises a source of alternating current of a preselected frequency, a code transmitting means, a phase modulating means and a traffic controlled relay. The immediate source of alternating current is a transformer TD whose primary winding 2 is connected to a generator, not shown, and which generator delivers alternating current of a preselected frequency. For example, the alternating current may be obtained from a transmission line or from a tuned vibrator operated from a local battery. The frequency of the current supplied by such generator may be of the order of 100 cycles per second which is the frequency generally used in present day cab signal systems, and which frequency provides satisfactory broken rail protection when track sections of the order of 5,000 feet in length are used. However, the frequency of the current supplied to transformer TD may be of the order of 20 cycles per second so that satisfactory broken rail protection for track sections of the order of 11,000 feet in length is provided, or the frequency may be of some intermediate frequency, such as 30 or 40 cycles per second.

The code transmitting means is here shown as a coder CD which may be of any one of several well-known forms, and it is sufficient for this application to point out that coder CD is provided with two code contact members 180 and 75 which are actuated in a cyclic operation as long as an operating winding 8 of the coder CD is supplied with current from any suitable source. For example, contact member 180 may be operated to alternately engage contacts 180a and 180b at the code rate of 180 times per minute, and contact member 75 may be operated to alternately engage contacts 75a and 75b at the code rate of 75 times per minute.

The phase modulating means may take different forms and as here shown it is a circuit network unit PM that includes an inductor 3 and a condenser 4 so proportioned and disposed that alternating current supplied to the input terminals 5 and 6 of the unit PM from secondary winding 7 of transformer TD is delayed to an extent sufficient that the phase of the alternating current appearing at the output terminals 9 and 10 of unit PM is different from that of the phase of the current applied to input terminals 5 and 6. The phase shift would be predetermined by the proportioning of the parts of the modulating unit PM, and may be for example a phase shift of the order of 100 degrees.

Traffic controlled relay HD is governed according to traffic conditions in advance of section D—E and as here contemplated relay HD is

picked up closing front contact 11 when the section in advance of section D—E is unoccupied and clear traffic conditions prevail, and relay HD is released closing back contact 12 when such section in advance is occupied and approach traffic conditions prevail. The apparatus for controlling relay HD is not shown, since such apparatus would be in accordance with standard practice and forms no part of my invention.

Current supplied to the rails at the exit end D of section D—E for transformer TD is phase modulated and coded according to the position of traffic controlled relay HD. To be explicit, when relay HD is picked up to close front contact 11, secondary winding 7 of transformer TD is connected across the rails over two alternative paths controlled by code contact member 180 of coder CD. One such path can be traced from the top terminal of secondary winding 7 over wire 13, a resistor 14, contact 180—180a, front contact 11 of relay HD, wire 15 to rail 1b, thence to rail 1a through a track relay to be referred to later, or through the train shunt of any train occupying the section, and from rail 1a over wire 16 to the lower terminal of secondary winding 7, wire 16 passing between terminals 10 and 6 of unit PM, as will be apparent from an inspection of the drawing. The other path includes top terminal of secondary winding 7, input terminal 5 of unit PM, inductor 3, output terminal 9, contact 180—180b of coder CD, front contact 11 of relay HD, and thence as traced for the first path back to the lower terminal of secondary winding 7, condenser 4 being connected across terminals 9 and 10. It is clear that current of the original phase is supplied to the rails over the first traced path closed at contact 180—180a of coder CD, and current phase shifted as predetermined by the proportioning of the unit PM is supplied to the rails over the second path closed at contact 180—180b of the coder. In other words, during the first half period of the cyclic operation of code contact member 180 of coder CD, non-modulated current is supplied to the rails, and each second code period of the cyclic operation of contact member 180, current of a predetermined phase modulation is supplied to the rails.

When control relay HD is released, closing back contact 12, transformer TD is connected across the rails over two alternative paths governed by code contact member 75. A first one of these two alternative paths extends from the top terminal of secondary winding 7 of transformer TD over wire 13, resistor 14, contact 75—75a of coder CD, back contact 12 of relay HD, wire 15 to rail 1b, thence through the track relay or train shunt to rail 1a and from rail 1a over wire 16 to the lower terminal of secondary winding 7. The other path of these two alternative paths includes modulating unit PM and contact 75—75b of coder CD as will be apparent from an inspection of the drawing. Consequently during each first half period of the cyclic operation of code contact member 75 and contact 75—75a is closed, non-modulated current is supplied to the track rails, and during each second half period of the cyclic operation of contact member 75 and contact 75—75b is closed current of the preselected phase modulation is supplied to the rails.

To sum up, when relay HD is picked up in response to a first or clear traffic condition, alternating current of a first predetermined code rate of a predetermined phase modulation is supplied to the rails of the section and when relay HD

is released in response to a second or approach traffic condition, alternating current of a second predetermined code rate and said predetermined phase modulation is supplied to the rails.

A track relay CF is connected across the rails at entrance end E of section D—E, and when the section is unoccupied, that is, when a train shown conventionally at TN does not occupy the section, relay CF is energized and picked up by the alternating current supplied to the rails by the transmitting apparatus located at the exit end D of the section. As here shown the relay CF is effectively energized and picked up when the section is unoccupied irrespective of the coding of the alternating current and is de-energized and released when the track section is occupied. Relay CF would be used to control apparatus associated with the section next in the rear of section D—E, and which apparatus would include a traffic controlled relay corresponding to relay HD for section D—E and controlled by traffic conditions of the section next in advance. The apparatus governed by relay CF is not shown for the sake of simplicity, since it would be in accordance with standard practice and forms no part of my invention.

The train shown conventionally at TN is provided with train carried receiving apparatus responsive to the phase modulated alternating current supplied to the rails of section D—E by the transmitting apparatus associated with that section as explained hereinbefore, and which train carried apparatus embodies my invention. In general such train carried receiving apparatus includes a receiving means, an amplifier-demodulating means, a code following relay, a decoding unit and a signaling means together with the necessary current sources. The receiving means includes inductors 17 and 18 which are mounted on train TN ahead of the leading pair of wheels over rails 1a and 1b, respectively, so that each inductor picks up an electromotive force corresponding in frequency, phase modulation and coding to that of the alternating current supplied to the rails by the transmitting apparatus.

In the present embodiment of my invention the use of two receiving channels is contemplated and each inductor 17 and 18 is connected to the input side of an amplifying electron tube, inductor 17 being associated with a tube VT1 and inductor 18 being associated with a tube VT2. Specifically, inductor 17 is connected to primary winding 19 of a transformer T1 over a condenser 20; and secondary winding 21 of transformer T1 and a condenser 22 in multiple are connected across grid 23 and cathode 24 of tube VT1, a battery 25 being included in the connection to cathode 24 to provide a desired grid bias voltage. Inductor 18 is connected to primary winding 26 of a transformer T2 over a condenser 27; and secondary winding 28 of transformer T2 and a condenser 29 in multiple are connected across grid 30 and cathode 31 of tube VT2, a battery 32 being included in the connection adjacent cathode 31 to provide a desired grid bias voltage. Tube VT1 is provided with a plate circuit that includes positive terminal B300 of a suitable source of direct current not shown, primary winding 33 of a transformer T3, plate 34 of tube VT1, intervening tube space to cathode 24 and negative terminal N300 of the same current source. Tube VT2 is provided with a plate circuit that includes terminal B300, pri-

mary winding 35 of a transformer T4, plate 36 of tube VT2, intervening tube space to cathode 31 and terminal N300.

Electron tubes VT1 and VT2, as well as other electron tubes of the receiving apparatus to be referred to later, are shown as of the indirect heater type although other types of tubes may be used if desired. The filaments of the several tubes are normally heated in the usual manner, such filament circuits being omitted from the drawing for the sake of simplicity. Consequently, the electromotive force picked up by inductor 17 is amplified by tube VT1 and the electromotive force picked up by inductor 18 is amplified at tube VT2, the amplified electromotive force appearing in the plate circuit of each of the two tubes having a frequency, phase modulation and code rate corresponding to that of the rail current. Furthermore, the two amplified electromotive forces caused by such coded rail current are of a predetermined phase relation with respect to each other, because such coded rail current flows in the two track rails in opposite directions at any given instant. Electromotive forces picked up by inductors 17 and 18 due to stray magnetic fields or magnetized rail spots, and which magnetic conditions ordinarily at least are of the same direction for both inductors or which excite one inductor only or both inductors out of step with each other, create electromotive forces in the plate circuits of the amplifier tubes that do not have the predetermined phase relationship with respect to each other or do not occur simultaneously.

The means of the train carried receiving apparatus for demodulating and detecting the phase modulated energy received by inductors 17 and 18 and amplified by the respective tubes VT1 and VT2, may take any one of several forms. The February, 1939 issue of the Proceedings of the Institute of Radio Engineers includes an article entitled "Communication by phase modulation" and wherein there are described four different means for receiving phase modulated energy, and it is clear from such article that any one of these four methods may be used with the train carried receiving apparatus of my invention. In the present embodiment of my invention, demodulation is contemplated by detecting each side band in combination with the carrier separately, and which method is the third listed method of the above cited publication.

In amplitude modulation the two side bands combine with the carrier in such a way that as the side band vectors rotate they add and subtract from the carrier and vary its amplitude, and detection can be accomplished by rectification of the carrier voltage. In phase modulation, the side band vectors rotate to shift the phase of the carrier but do not change its amplitude. However, one side band above would combine with the carrier to change its amplitude as the side band vector rotates, but the envelope of the modulated carrier would contain a strong second harmonic especially if the percentage of modulation is high. Hence, demodulation of the phase modulated energy can be effected by the use of two filters, one of which passes the carrier and the upper side band frequency and the other of which passes the carrier and the lower side band frequency. Each filter feeds a conventional detector tube, and the output voltages of these detector tubes, are combined in a push-pull circuit. This push-pull

arrangement combines the detector outputs in phase to cancel the second and other even harmonics and leave the fundamental and all odd harmonics with the result that there is created in the output of such detector tubes an electromotive force that is varied at a rate corresponding to the rate at which the carrier is phase modulated.

Since two receiving channels are used, one for the electromotive force picked up from rail 1a, and one for the electromotive force picked up from rail 1b, two such demodulating filters and detector tubes are coupled to the output of each of the amplifying tubes VT1 and VT2. Again referring to the drawing, transformer T3 whose primary winding 33 is included in the plate circuit of tube VT1, is provided with two secondary windings 37 and 38, winding 37 being connected to an upper side band filter AF1 and winding 38 being connected to a lower side band filter BF1. Likewise, transformer T4 whose primary winding 35 is included in the plate circuit of tube VT2 is provided with two secondary windings 39 and 40, winding 39 being connected to an upper side band filter AF2 and winding 40 being connected to a lower side band filter BF2. These filters AF1, AF2, BF1 and BF2 are preferably similar in their arrangements and each consists of inductance and capacitance as will be readily understood by an inspection of the drawing. Each filter AF1 and AF2 is proportioned and adjusted to pass the carrier and upper side band and to suppress other frequencies, and each filter BF1 and BF2 is proportioned and adjusted to pass the carrier and lower side band and suppress other frequencies.

Filter AF1 includes primary winding 41 of a transformer T5 whose secondary winding 42 is connected across grid 43 and cathode 44 of a detector tube VT3, a biasing battery 45 being preferably included in the connection. Filter BF1 includes primary winding 46 of a transformer T6 whose secondary winding 47 is connected across grid 48 and cathode 49 of a detector tube VT4, biasing battery 50 being included in the connection. Detector tubes VT3 and VT4 are provided with a push-pull arrangement of plate circuits, one primary winding 51 of a transformer T9 being included in the plate circuit of tube VT3 and another primary winding 52 of transformer T9 being included in the plate circuit of tube VT4. Both of these plate circuits are connected to a common source of current, such as, the B300—N300 source of direct current.

Filter AF2 includes a primary winding 53 of a transformer T7 whose secondary winding 54 is connected across grid 55 and cathode 56 of a detector tube VT5, a biasing battery 57 being included in the connection; and filter BF2 includes primary winding 58 of a transformer T8 whose secondary winding 59 is connected across grid 60 and cathode 61 of a detector tube VT6, a biasing battery 62 being included in the grid circuit. Tubes VT5 and VT6 are provided with a push-pull arrangement of plate circuits, one primary winding 63 of a transformer T10 being included in the plate circuit of tube VT5 and another primary winding 64 of transformer T10 being included in the plate circuit of tube VT6, and the two plate circuits being connected to the B300—N300 current source.

It follows that each change from non-modulated energy to modulated energy and from modulated energy back to non-modulated energy of the rail current creates a variation in the output

of each of the two demodulators. In other words, an electromotive force is created in secondary winding 65 of transformer T9 of the demodulator including filters AF1 and BF1, and tubes VT3 and VT4, as the result of the phase modulated energy picked up by inductor 17, and a similar electromotive force is created in secondary winding 66 of transformer T10 of the demodulator including filters AF2 and BF2, and tubes VT5 and VT6, as the result of the phase modulated energy picked up by inductor 18.

The electromotive forces of secondary windings 65 and 66 of transformers T9 and T10, respectively, are used to operate a code following relay MR through the means of a mixer tube VT7 and a transformer T11. Secondary winding 65 of transformer T9 is connected across a first grid 67 and cathode 68 of tube VT7, and secondary winding 66 of transformer T10 is connected across a second grid 69 and cathode 68 of tube VT7. A biasing battery 70 is common to the two grid circuits of tube VT7 to provide a negative grid bias voltage for tube VT7 such that plate circuit current flows only when the electromotive forces of secondary windings 65 and 66 are applied to the grids 67 and 69 simultaneously and in phase.

Tube VT7 is provided with a plate circuit including the B300—N300 current source and primary winding 71 of transformer T11, the secondary winding 72 of transformer T11 being connected to the code following relay MR. As stated above, the arrangement is such that when the two electromotive forces created in secondary windings 65 and 66 are applied to tube VT7 simultaneously and in phase a plate circuit current flows and consequently an electromotive force is induced in secondary winding 72 of transformer T11 and an energizing current impulse is in turn applied to relay MR for operating that relay. It follows that the code following relay MR is operated at a rate corresponding to the code rate at which the rail current is phase modulated.

Code following relay MR controls two control relays A and L through a decoding unit DU. This decoding unit DU may be of any one of several well-known forms and is shown conventionally for the sake of simplicity since its specific structure forms no part of my invention. For example, decoding unit DU may be of the standard tuned circuit arrangement, and it is sufficient for this application to point out that when relay MR is operated at a rate corresponding to the 180 code rate of phase modulation of the rail current, control relays A and L are both picked up, and when relay MR is operated at a rate corresponding to the 75 code rate of phase modulation of the rail current, relay L is picked up and relay A is released. Also, relays A and L are both released when the code following relay MR is inactive.

Control relays A and L are used to control in turn a train control device such as a multiple position cab signal CS. The arrangement is such that when relay A is picked up to close front contact 73, a circuit is formed for a green lamp G of signal CS and lamp G is illuminated as a clear signal indication. When the relay A is released closing back contact 74 and relay L is picked up to close front contact 75, a circuit is formed for yellow lamp Y of signal CS and lamp Y is illuminated as an approach signal indication; and when relays A and L are released closing back contacts 74 and 76, respectively, a circuit is formed for red lamp R of signal CS and

lamp R is illuminated as a slow speed signal indication.

In describing the operation of the apparatus I shall assume that train TN occupies track section D—E at a time when control relay HD is picked up due to clear traffic conditions and the alternating current supplied to the rails at exit end D is phase modulated at the code rate of 180. Such coded rail current flows in the rails in opposite directions at any given instant and induces electromotive forces in each inductor 17 and 18 and each of which electromotive forces is phase modulated at a code rate corresponding to that of the rail current. The electromotive force picked up by inductor 17 is applied to the receiving channel including amplifier tube VT1 and the demodulator comprising filters AF1 and BF1 and detector tubes VT3 and VT4, and by which receiving channel such electromotive force is amplified and demodulated causing an electromotive force having a code rate that corresponds to the code rate of the phase modulation of the electromotive force picked up from rail 1a, to be created in secondary winding 65 of the transformer T9. The electromotive force picked up by inductor 18 is applied to the receiving channel including amplifier tube VT2 and the demodulator comprising filters AF2 and BF2 and detector tubes VT5 and VT6, and by which receiving channel such electromotive force is amplified and demodulated to cause in secondary winding 66 of transformer T10 an electromotive force having a code rate that corresponds to the code rate of the phase modulation of the electromotive force picked up from rail 1b. These two output electromotive forces created in secondary windings 65 and 66 are applied simultaneously to the mixer tube VT7 and as a result an energizing current impulse is applied to the code following relay MR, relay MR being therefore operated at a rate which corresponds to the 180 code rate of the phase modulation of the rail current. Such rate of operation of code following relay MR effectively energizes relay A and relay A on picking up causes lamp G of signal CS to be illuminated to display a clear signal indication.

In the event train TN occupies section D—E when relay HD is released in response to approach traffic conditions and the alternating current is phase modulated at the code rate of 75, the operation of the train carried receiving apparatus is the same as described in connection with the 180 code rate for the phase modulation of the rail current except for the fact of the code rate of the electromotive forces created in secondary windings 65 and 66 are of the 75 code rate and relay MR is operated at a corresponding rate. With code following relay MR operated at a rate corresponding to the 75 code rate, relay L is picked up and relay A is released and lamp Y of signal CS is illuminated as an approach signal indication.

In the event a train occupies section D—E ahead of the train TN and thereby shunts the rail current away from train TN, no energy is picked up by inductors 17 and 18 and relay MR is inactive, with the result that both relays A and L are released and lamp R of signal CS is illuminated to display a slow speed indication. It is to be pointed out that if the energy level of the electromotive forces picked up by inductors 17 and 18 is relatively high, the amplifying tubes VT1 and VT2 may be omitted and inductors 17 and 18 connected directly to the corresponding demodulators.

Again, it is apparent that inductors 17 and 18

may be connected together and the two inductors connected to a single receiving channel, such as the channel including tube VT1 and the demodulator comprising filters AF1 and BF1, and the detector tubes VT3 and VT4. Under such conditions the mixer tube VT7 would be provided with one control grid and that grid connected to the output of the demodulator and biased so that a corresponding impulse of current flows in the plate circuit of tube VT7 whenever an electromotive force is applied to its control grid.

It is also to be noted that the particular phase shift used in the phase modulation is not critical. However, the effective amplitude of the modulation frequency increases as the phase shift increases, and the resulting increase in the third harmonic would not disturb the operation of the code following relay. A mathematical analysis shows that a phase shift of the order of 100 degrees would produce about 1.7 times the power saving obtained by a phase shift of one radian, and 180 degrees phase shift would show a power saving of about 1.86. It is to be observed that if a phase shift of 180 degrees is used, the coder CT could be arranged with pole changing contacts instead of the make-and-break contacts and unit PM omitted so that the relative polarity of the track current would be reversed at each operation of the coder.

Advantages of the apparatus here disclosed for a signal system results in more power being applied to the control or transmitting circuit for a given transmitter. Such power gain for a cab signal system results in the particular advantages of operating a cab signal over track sections of 11,000 feet of length on a carrier frequency which provides satisfactory broken rail protection. Such power gain results in a reduction of the interference created by stray magnetic fields and magnetized rail spots. Also a two channel arrangement for the receiving apparatus reduces the interference of stray magnetic fields and has the additional advantage that satisfactory broken rail protection is obtained for carrier frequencies of the order of 40 cycles per second when used in track circuits of 11,000 feet in length.

Although I have herein shown and described only one form of apparatus embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In combination, a control circuit, a source of alternating current, a code transmitter operative to periodically operate a contact member to alternately engage a first and a second contact at a predetermined code rate, a modulating unit including inductance and capacitance, circuit means including two alternative paths to connect said current source to said control circuit to supply current thereto, one of said paths including said contact member and first contact to supply to said control circuit such alternating current non-modulated and the other of said paths including said modulating unit in series with said contact member and second contact to impress on the current supplied to the control circuit a phase modulation predetermined in phase shift by said modulating unit, a demodulator operative to create current impulses in response to such phase modulation of such alternating current, decoding means peculiarly responsive to current impulses of said code rate, a signal connected to

said decoding means, and circuit means to couple the control circuit to said demodulator and said demodulator to said decoding means to control said signal by said current supplied to the control circuit.

2. In combination, a control circuit, a source of alternating current, a modulating unit including reactance and having input terminals connected to said current source, a code contact member operable to alternately engage a first and a second contact at preselected code rate, a first circuit path including said contact member and said first contact to connect said current source to said control circuit, a second circuit path including said contact member and said second contact to connect the output terminals of said modulating unit to the control circuit, said first and second circuit paths effective to cause the current supplied from said source to the control circuit to be characterized by a predetermined code rate of phase modulation; and receiving apparatus including a phase demodulator, a decoder and a signal and connected to the control circuit to actuate said signal in response to the current thus supplied to the control circuit.

3. In combination, a control circuit; transmitting apparatus including a source of alternating current, a phase modulator including inductance and capacitance, a coding device having a contact member alternately operated to a first and a second position, said current source alternately connected to said control circuit through the first position of said contact member and through the second position of the contact member in series with said modulator to supply thereto such alternating current characterized by alternate periods of current non-modulated and periods of current modulated to have a predetermined phase shift; two inductors coupled to said control circuit to pick up two electromotive forces each characterized by the code rate of phase modulation of the control circuit current, two demodulators one connected to each inductor and each said demodulator operative to create current impulses of said code rate in response to the electromotive force picked up by the respective inductor, decoding means peculiarly operative in response to current impulses of said code rate and connected to said demodulators in multiple for operation thereof only when the current impulses created by the demodulators occur simultaneously, and a signal governed by said decoding means.

4. In combination; transmitting apparatus including a source of alternating current, a phase modulator having inductance and capacitance and a coding device having a contact member operable to a first and a second position to alternately connect said modulator in series with said source and shunt said source around the modulator to supply such alternating current characterized by a preselected code rate of a predetermined phase modulation; a control circuit including two adjacent conductors to form opposite sides of said circuit and said control circuit connected to said transmitting apparatus to be supplied by said coded and modulated alternating current, two inductors one coupled to each of said conductors to pick up two electromotive forces each characterized by said code rate of said phase modulation and which electromotive forces have a predetermined relative polarity with respect to each other, two demodulators one connected to each of said inductors and each demodulator effective to create current impulses of a rate corresponding to said code rate of said phase modulation in response to the electromotive force

picked up by the respective inductor, a mixer electron tube provided with two grids, said two grids connected one to one of said demodulators and the other to the other one of said demodulators to create a current impulse in the plate circuit of said mixer tube only when two current impulses one from each demodulator are applied to said grids simultaneously and at a preselected relative polarity, and signaling means coupled to said mixer tube plate circuit effectively controlled by the code rate of current impulses thus caused to flow in said plate circuit.

5. In combination, a source of alternating current, a phase modulator including inductance and capacitance to create a predetermined phase shift of the current from said source, a coder including a contact member operated to alternately engage a first and a second contact at a preselected code rate, a control circuit having adjacent conductors as opposite sides of the circuit, circuit means including alternative paths to connect said source across said control circuit conductors, one of said paths including said first contact and the other of said paths including said modulator and said second contact to cause

the current supplied to said control circuit to be of substantially a given amplitude but having recurrent periods during which the current has said predetermined phase modulation, two inductors one coupled to each of said conductors to receive two electromotive forces each having a phase modulation corresponding to that of the current in the respective conductor, two phase demodulators one connected to each of said inductors to create two groups of current impulses each group having a code rate corresponding to the code rate of the phase modulation of the electromotive force of the respective inductor, a mixer tube provided two grids one of which is connected to one of said demodulators and the other to the other of said demodulators to create a predetermined variation in the plate current of the mixer tube when its two grids are simultaneously excited by the two groups of current impulses, a relay coupled to said plate circuit and operated in response to such variations of plate current, and signaling means controlled by said relay and effectively energized only when said relay is operated at a rate corresponding to said code rate.

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