

Aug. 24, 1965

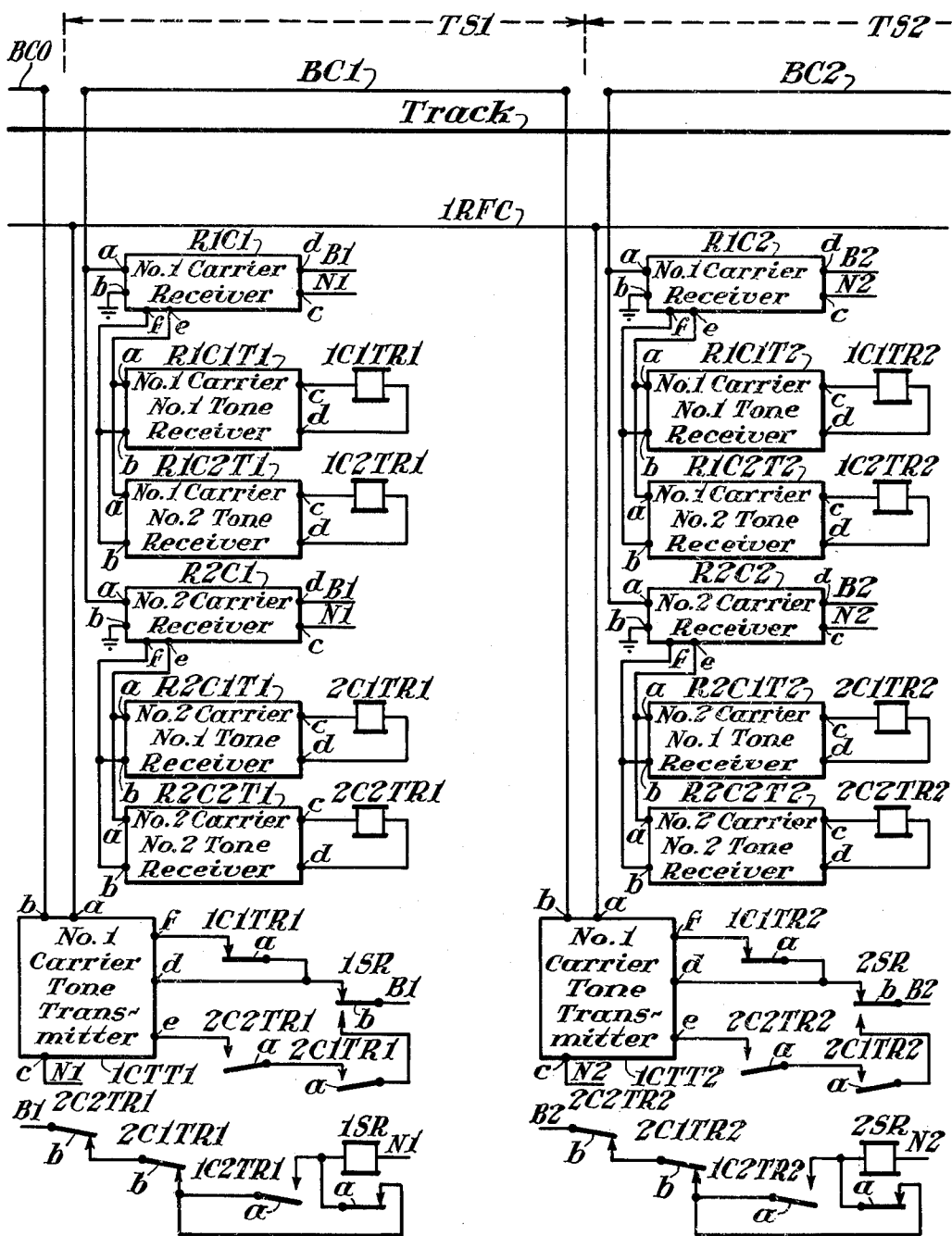
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3,202,816

AUTOMATIC TRAIN OPERATION SYSTEM

Filed April 10, 1961

4 Sheets-Sheet 1



Loc. 1.

Fig. 1.

Loc. 2.

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4 Sheets-Sheet 2

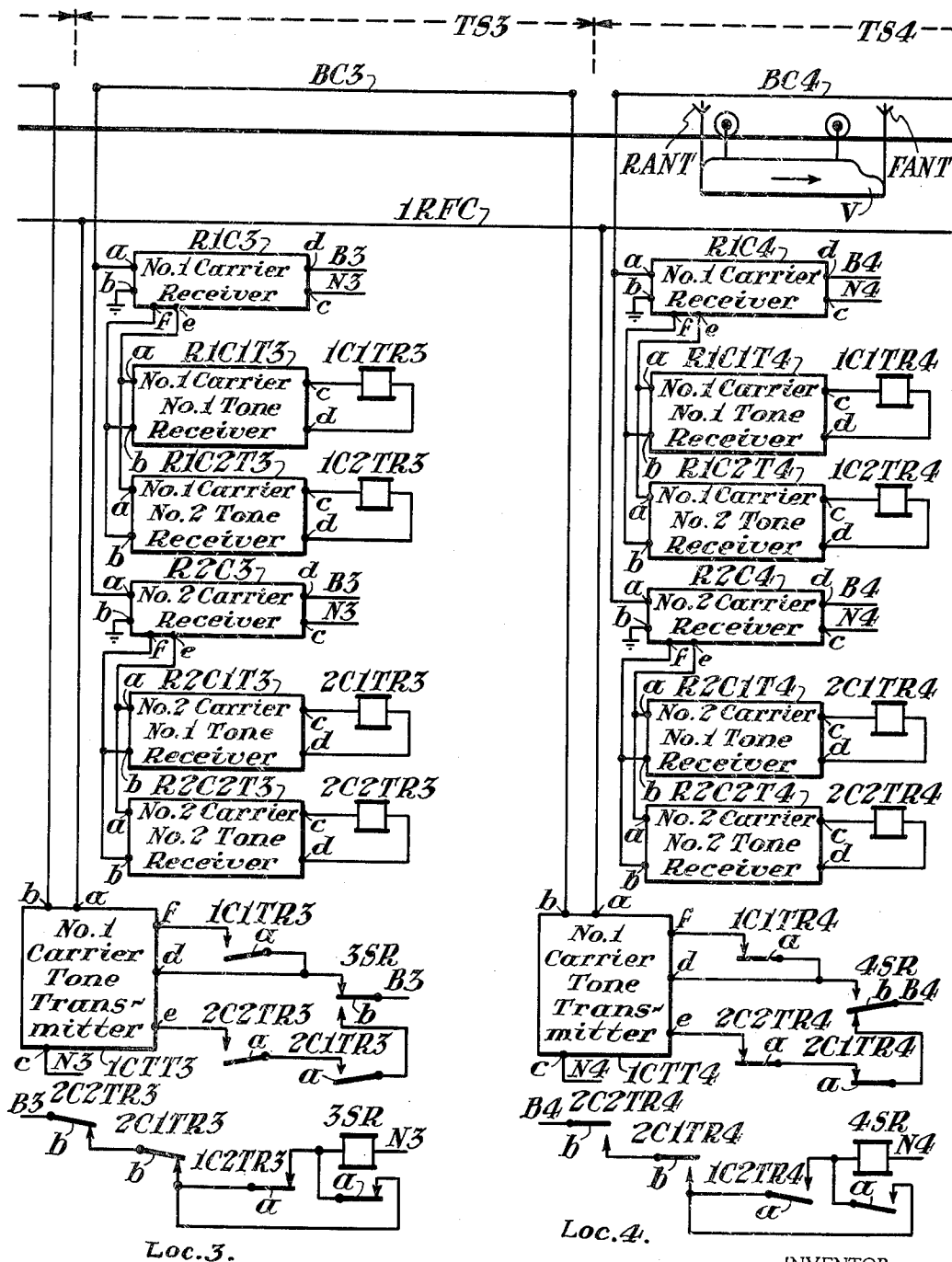


Fig. 2.

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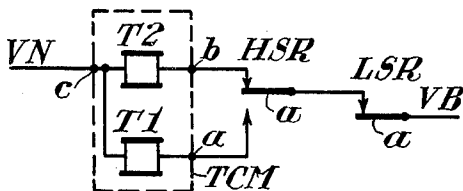
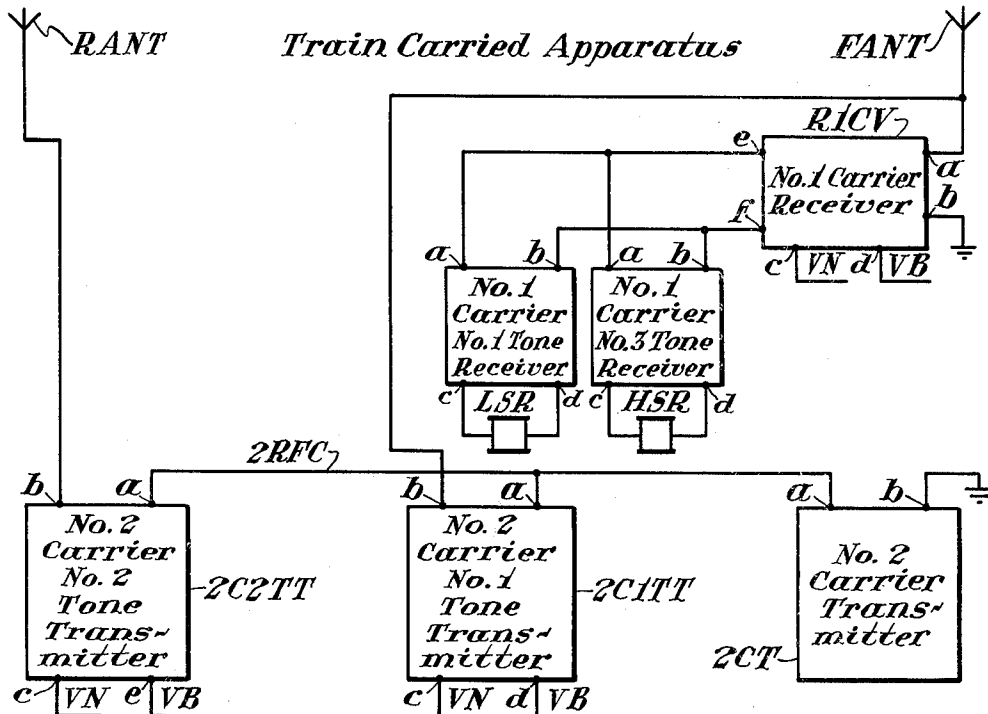
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AUTOMATIC TRAIN OPERATION SYSTEM

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Controls Engine to Low and High Speeds when Relays T1 and T2, Respectively are Energized **Fig. 4.**

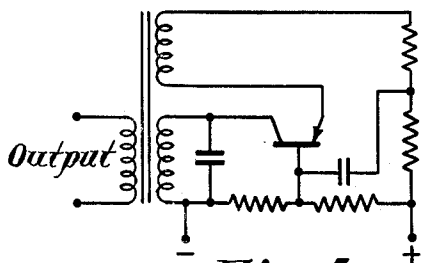
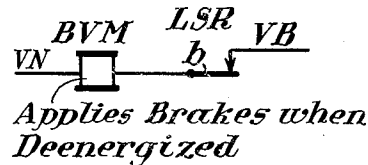


Fig. 5.

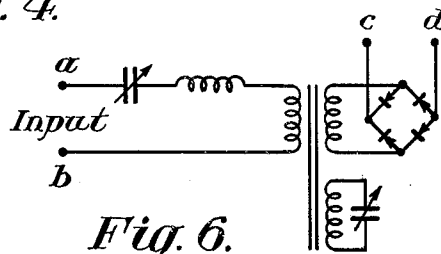


Fig. 6.

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AUTOMATIC TRAIN OPERATION SYSTEM
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6 Claims. (Cl. 246-63)

My invention relates to an automatic train operation system and particularly to a train operation system for automatically controlling the movements of trains in a single direction over a stretch of railway track, especially of the monorail type.

There is shown and described in the copending application, Serial No. 90,493, filed February 20, 1961, by Frank T. Pascoe and Leslie R. Allison, for Automatic Train Operation System, which application is assigned to the same assignee as the present application and has issued as Patent No. 3,041,448, dated June 26, 1962, a train operation system for operatorless trains traversing a stretch of railway track in which no track circuits are or can be provided. In the system of this prior patent, provisions are made for following train movements. Each following train is automatically controlled, in accordance with the distance between it and the immediately preceding train, by apparatus actuated over a plurality of electrical signaling conductors extending from each of a series of locations in the track stretch to the next preceding location in said stretch. As is well known, the installation and maintenance of electrical conductors extending between locations relatively distant from each other is expensive and, if such conductors consist of line wires supported by poles, they constitute a source of trouble due to wind, snow, etc.

It is accordingly the main object of my invention to provide an improved system similar to that covered by said prior patent but in which only a single electrical signaling conductor is required between each location in the track stretch over which the trains are to travel.

It is a second object of my invention to provide an automatic train operation system which requires a smaller number of relays than the prior art systems.

In accomplishing the foregoing objects of my invention, I employ apparatus at each of a series of locations along a railway track stretch for selectively supplying, in accordance with traffic conditions in advance of the respective location, one or more of a plurality of distinct signals to a block conductor extending between the respective location and the preceding location in the track stretch. In other words, the several distinct signals are transmitted from each location over the block conductor extending from that location toward the last prior location which an approaching train passes, which is hereinafter designated as the preceding location. Signal receiving means are provided on each train which travels the stretch to receive from the block conductor, for the section or block of the track stretch over which the train is then traveling, selected ones of the signals supplied to that conductor to control the train in accordance with the received signal or signals. The signals supplied to the preceding block conductor at each location are also supplied to signal receiving apparatus connected to that conductor at the preceding location. The signal receiving apparatus at each location operates to selectively supply a similar plurality of distinct signals over the next block conductor to the next preceding location. I also provide on each train to travel the track stretch apparatus for transmitting to the block conductor for the track section over which the respective train is traveling, a second plurality of distinct signals which are employed by apparatus at the entrance end of the respective track

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section to reflect the entrance of the train into that section and the occupancy of the track section by that train so long as such train remains in such section.

Other objects and characteristic features of my invention will become apparent as the description proceeds.

I shall first describe one embodiment of my invention, and shall then point out the novel features thereof in claims.

In the accompanying drawings, FIGS. 1, 2 and 3 when arranged in that order from left to right comprise a diagrammatic view of a stretch of railway track provided with the signal control apparatus, and the signal transmitting and receiving apparatus embodying my invention at each of a series of locations in the track stretch.

FIG. 4 comprises a diagrammatic view of the train-carried signal transmitting and receiving apparatus, and train control apparatus for automatically operating trains in accordance with received signals.

FIG. 5 is a circuit drawing of a typical tone transmitter which may be employed in my invention for transmitting signals.

FIG. 6 is a circuit drawing of a typical tone receiver which may be used for receiving the transmitted signals.

In each of the drawings similar reference characters designate similar parts of the apparatus.

Referring to FIGS. 1 through 3, arranged numerically in that order from left to right, there is illustrated a stretch of monorail railway track over which trains travel in a direction from west to east, or from left to right as shown in the drawings. While I have illustrated my invention as being employed in a monorail railway system it is to be understood that the invention could just as well be employed in a conventional two-rail railway system or in any system in which vehicles move in a single direction over a trackway provided for the guidance of the vehicles along a predetermined route. In the stretch of monorail railway track illustrated in FIGS. 1 through 3 there is shown a succession of locations designated, in the order from left to right, Loc. 1 through Loc. 5. This arrangement will be readily apparent from an inspection of the drawings.

A plurality of signal blocks TS1 through TS5 is provided in the track stretch, not by insulated rail joints designating the ends of the signal blocks in the conventional manner, but by sections of a sectionalized electrical block conductor. There is thus a succession of block conductors, one for each signal block, each of which conductors extends the length of and defines the ends of the respective signal block. Each block conductor or block conductor section is designated by the reference character BC followed by a numerical suffix corresponding to the numerical suffix of the signal block, the limits of which are defined by the ends of the respective block conductor or conductor section. For example, in FIG. 1 the limits of signal block TS1 are defined by the ends of block conductor or conductor section BC1 which extends between Locs. 1 and 2. Similarly, in FIGS. 1 and 2 the limits of signal block TS2 are defined by the ends of block conductor BS2 which extends between Locs. 2 and 3. The arrangement of the signal blocks and block conductors for the remainder of the track stretch shown in FIGS. 1 through 3 will be readily apparent from the examples given and from a brief examination of such drawing figures. It should be pointed out that each block conductor or section of block conductor extends parallel with the section of track included in the corresponding signal block and in close proximity thereto so that closely spaced coupling may continuously be provided between each respective conductor and a signal receiving device provided on each of the trains to travel the track stretch. This arrangement will become more apparent later in this description.

It is expedient at this point in the description to point out that two channels are provided for communication or the transmission of control signals between each of Locs. 1 through 5, and the trains traversing the track stretch and to be controlled. These channels are shown in the accompanying drawings as each being a radio circuit with a distinct carrier current channel capable of carrying several voice frequency or other low frequency carrier tones, hereinafter often referred to as signals, but each may alternatively be an inductive carrier channel. Carrier transmitters 1CT and 2CT shown conventionally in FIGS. 3 and 4, respectively, provide first and second basic carrier currents, respectively, for the communication channels, and each transmitter is assumed to have a self-contained power supply for supplying power for operation of the respective transmitter. Two output terminals *a* and *b* are provided on each transmitter, terminal *b* of each transmitter being connected to ground. Terminal *a* of transmitter 1CT is connected to an electrical conductor 1RFC which extends to each of the Locs. 1 through 5 to supply to each location the basic carrier current for the first basic communication channel. Terminal *a* of train-carried transmitter 2CT connects to a conductor 2RFC to supply to two train-carried tone transmitters 2C1TT and 2C2TT, to be discussed, the basic carrier current for the second basic communication channel. For the purpose of the remainder of this description it will be assumed that the communication channels are space radio channels. However, it is to be understood that the actual coupling is between the antennas on the train and the immediately adjacent portion of a block conductor. If as previously mentioned, inductive carriers are to be used as the communication channels, the carrier transmitters 1CT and 2CT would be ones suitable for such type of channel. The purpose of supplying the carrier current from transmitter 1CT over conductor 1RFC to each of Locs. 1 through 5 will be more fully explained later. It is to be understood that, for convenience and simplicity, only a single No. 1 carrier current transmitter has been shown, which supplies the basic carrier current of that frequency to all locations over line conductor 1RFC. In actual practice, an identical carrier current transmitter would preferably be provided at each location to supply locally the basic carrier for transmitting the tone signals over the block conductor to the preceding location.

It should be pointed out at this time that energy for the operation of direct current apparatus at each of Locs. 1 through 5 is furnished by a suitable source of current, preferably a battery of proper voltage and capacity, provided at each of said locations. For the sake of simplicity these power sources are not shown in the drawings but the positive and negative terminals of each source are identified by reference characters B and N, respectively, followed by a suffix designating the location of each respective source. For examples, the positive and negative terminals of the power source at Loc. 1 are designated B1 and N1, respectively, and the positive and negative terminals of the source at Loc. 4 are designated B4 and N4, respectively.

A train or vehicle designated V is shown occupying the track section in signal block TS4. As previously mentioned, this vehicle travels over the track stretch in a direction from west to east as indicated by the arrow on the vehicle and each end of the vehicle is provided with a signal coupling device, each such device being here shown as an antenna. The antenna on the front end of vehicle V is designated FANT and that on the rear end of the vehicle is designated RANT, and these antennas are, as previously mentioned, located on their respective ends of the vehicles so as to provide closely spaced coupling with the block conductors BC1 through BC5 as the vehicle traverses the track stretch. Although I have chosen to show the signal coupling devices employed in my invention as conventional antennas, these

devices may in practice take the form of any suitable sort of signal coupling device such as loop antennas, pickup coils, or any other such device suitable for receiving the signals supplied to the block conductors and transmitting signals to such conductors. It is to be understood that vehicle V is shown so that a complete operational example of the apparatus of my invention may be hereinafter given, and that in actuality all trains or vehicles to traverse the track stretch will be equipped similarly to vehicle V.

Before proceeding further with the description it is desired to point out that a plurality of relays which will be hereinafter discussed are shown in the drawings in the conventional manner. The contacts of these relays are in most instances not disposed on the drawings directly below the geometric rectangles representing the respective relay windings but, where the contacts are not so disposed, the reference character designating the respective relay winding controlling each contact appears on the drawing directly above each contact. This arrangement is apparent from a brief inspection of the drawings.

There is provided at each of Locs. 1 through 5 a tone transmitter unit, each comprising a plurality of tone or signal transmitters. These transmitter units at Locs. 1 through 5 are designated 1CTT1 through 1CTT5, respectively. Transmitter unit 1CTT5 at Loc. 5 (FIG. 3) is the only unit that is shown in any detail, this unit comprising three tone or signal transmitters for producing tones designated No. 1 tone, No. 2 tone and No. 3 tone. The transmitter units at Locs. 1 through 4 are similar to unit 1CTT5 and, therefore, for purposes of simplicity only the internal arrangement of transmitter 1CTT5 is shown in any detail since the internal arrangement of tone transmitter units 1CTT1 through 1CTT4 will be readily understood from a description of unit 1CTT5.

Referring to FIG. 3, each tone transmitter of transmitter unit 1CTT5 produces, when energized, a different carrier current or tone of a frequency level that may be used to modulate the first basic carrier current previously discussed and supplied to conductor 1RFC from carrier transmitter 1CT (FIG. 3). It will be understood that the No. 1 tone or signal transmitters provided in each of the units 1CTT1 through 1CTT4 at Locs. 1 through 4, respectively, produce tones or signals of the same frequency level as the No. 1 tone transmitter at Loc. 5. Similarly, the No. 2 and No. 3 tone or signal transmitters provided in each of the units 1CTT1 through 1CTT4 at Locs. 1 through 4, respectively, produce tones or signals of the same frequency level as the No. 2 and No. 3 tone transmitters, respectively, at Loc. 5.

Each tone or signal transmitter comprises a simple transistor oscillator circuit with an output winding on the feedback transformer as shown in FIG. 5. The oscillator circuit becomes active when a relatively low voltage direct current source is connected across the positive (+) and negative (−) terminals shown in FIG. 5 and also shown in FIG. 3 for each transmitter. Any other oscillator circuit arrangement which will provide similar results may also be used. The operation of such oscillator circuit arrangements is well known and no further description thereof is required. The output windings of the tone transmitters in unit 1CTT5 are connected in series across terminals *a* and *b* provided on that unit (FIG. 3), terminal *a* being connected to the carrier frequency conductor 1RFC, and terminal *b* being connected to signal block conductor BC4. By this arrangement the basic carrier frequency supplied to terminal *a* of unit 1CTT5 from conductor 1RFC may be modulated by one or more of the carrier tones and supplied from terminal *b* of unit 1CTT5 to conductor BC4. Such modulation of carrier currents by lower frequency carrier tones is well known and, it is believed, may be fully understood from this brief description.

A plurality of additional terminals *c*, *d*, *e* and *f* are also provided on transmitter unit 1CTT5 and these ter-

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minals are connected internally in the unit to the tone transmitters to provide for modulation control. Terminal *c* is connected in multiple to the negative terminal (—) of each of the tone transmitters in unit 1CTT5 and externally is connected to negative terminal N5 of the battery at Loc. 5. Terminals *d*, *e* and *f* connect to the positive (+) terminals of the No. 1, No. 2 and No. 3 tone transmitters, respectively, and, as outlined above, the carrier current is modulated by the respective carrier tones according as energy from positive terminal B5 of the battery at Loc. 5 is supplied to said terminals *d*, *e* and *f*. In a similar manner, terminal *c* of each other tone transmitter unit is connected to the negative terminal of the battery at the respective location while terminals *d*, *e* and *f* of these units are selectively connected to the positive terminal of the corresponding battery. The circuits for selectively supplying energy to terminals *d*, *e* and *f* of these transmitter units will be discussed later.

There is provided at each of the locations 1 through 5 a plurality of relays, carrier receivers and tone receivers, the corresponding apparatus at each such location having similar functions as hereinafter described. Corresponding apparatus at each of Locs. 1 through 5 are designated by similar reference characters except that the numerical suffixes of the reference characters are changed at each location to agree with the numerical designation of that location.

Since the apparatus and circuits at each location, except as heretofore and hereinafter pointed out, is substantially identical, Loc. 2 has been selected as a typical location and the apparatus and circuits at that location will be described in detail.

These is illustrated conventionally in FIG. 1 in connection with location 2 first and second carrier receivers R1C2 and R2C2, respectively, and an input terminal *a* on each receiver is shown connected to block conductor BC2. A second terminal *b* on each receiver is shown connected to ground in the usual manner. These carrier receivers R1C2 and R2C2 are capable of receiving the first and second basic carrier currents, respectively, supplied as hereinafter described to the previously discussed block conductor BC2, and each is capable of providing an output which includes any of the associated modulating tones which is supplied to conductor BC2. It is to be understood that receiver R1C2 and receiver R2C2 receive carrier current of the respective frequency from block conductor BC2 only. Terminals B2 and N2 of the power source of Loc. 2 are connected to terminals *d* and *c*, respectively, of receivers R1C2 and R2C2 to provide energy for operation of the receivers.

Output terminals *e* and *f* on receiver R1C2 are connected in multiple to input terminals *a* and *b*, respectively, on No. 1 and No. 2 tone receivers designated R1C1T2 and R1C2T2, respectively. Similarly, output terminals *e* and *f* on receiver R2C2 are connected in multiple to input terminals *a* and *b*, respectively, on No. 1 and No. 2 tone receivers designated R2C1T2 and R2C2T2, respectively. Each tone receiver is provided with output terminals *c* and *d* across which the winding of a relay is connected. The relay connected to terminals *c* and *d* of the No. 1 carrier-No. 1 tone receiver R1C1T2 is designated 1C1TR2, the relay connected to terminals *c* and *d* of the No. 1 carrier-No. 2 tone receiver R1C2T2 is designated 1C2TR2, and the relays connected to terminals *c* and *d* of the No. 2 carrier-Nos. 1 and 2 tone receivers R2C1T2 and R2C2T2, respectively, are designated 2C1TR2 and 2C2TR2, respectively.

A typical circuit for a tone receiver that may be employed is shown in FIG. 6. This receiver is provided with input terminals *a* and *b* and output terminals *c* and *d* the input terminals corresponding with the input terminals *a* and *b* on each of the receivers shown at Loc. 2 in FIG. 1. The receiver shown in FIG. 6 includes filter circuits, and each of the receivers shown at Loc. 2 in FIG. 1 is to be understood to include similar filter

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circuits that select only the signal or tone frequency of the respective receiver. Output terminals *c* and *d* on the receiver shown in FIG. 6 correspond to the output terminals *c* and *d* of each tone receiver shown at Loc. 2 in FIG. 1. Therefore, the output from the transformer winding included in each tone receiver at Loc. 2 in FIG. 1 is rectified and supplied to the corresponding output terminals *c* and *d*. Relays 1C1TR2, 1C2TR2, C1TR2 and 2C2TR2 are, therefore, energized only when current of the correct carrier and tone frequency, that is, No. 1 carrier-No. 1 tone; No. 1 carrier-No. 2 tone; No. 2 carrier-No. 1 tone; and No. 2 carrier-No. 2 tone, respectively, is received at that location. Operation of the receiver circuit shown in FIG. 6 is well known and it is to be understood that other well known receiver circuits may be used. It is considered sufficient for purposes of this description to point out that when one or more tone frequencies are transmitted over one of the carrier current communication channels, they are selectively received only by the corresponding carrier and tone receivers, and the corresponding relays, such as relay 1C1TR2, 1C2TR2, 2C1TR2 or 2C2TR2 at Loc. 2, are thereby energized.

There is also provided at Loc. 2 a stick relay designated 2SR. This relay has a pickup circuit which may be traced from terminal B2 of the battery at Loc. 2 over back contact *b* of relay 2C2TR2, back contact *b* of relay 2C1TR2, front contact *a* of relay 1C2TR2 and through the winding of relay 2SR to battery terminal N2. Relay 2SR is provided with a stick circuit which extends from terminal B2 of the battery over back contact *b* of relay 2C2TR2, back contact *b* of relay 2C1TR2, front contact *a* of relay 2SR and through the winding of the relay to battery terminal N2. Relay 2SR therefore becomes picked up whenever relays 2C2TR2 and 2C1TR2 are released and relay 1C2TR2 is picked up, and once picked up, remains picked up so long as relays 2C2TR2 and 2C1TR2 remain released. From the above detailed description of the control circuits for the relays at Loc. 2, it is apparent that the SR relay at each location is provided with control circuits which are operated by the 1C2TR, 2C1TR and 2C2TR relays at the respective location.

The circuits for controlling the signal or tone transmitter units 1CTT1 through 1CTT5 to transmit their various carrier tones or signals will now be described. As previously outlined, transmitter unit 1CTT5 (FIG. 3) is capable of transmitting first, second and third tones or signals. These signals represent a low speed control signal, a stick relay control signal and a high speed control signal, respectively.

The circuit for supplying energy from battery terminal B5 to terminal *d* of transmitter unit 1CTT5 and thereby energizing the No. 1 tone transmitter to transmit a low speed signal, extends from said battery terminal over the front point of contact *b* of relay 5SR to terminal *d* of unit 1CTT5. The circuit for supplying energy to terminal *e* of unit 1CTT5 and thereby causing the No. 2 tone to be transmitted extends over the back point of contact *b* of relay 5SR, front contact *a* of relay 2C1TR5, and front contact *a* of relay 2C2TR5 to said terminal *e*. Energy is supplied to terminal *f* of unit 1CTT5 over a circuit extending from battery terminal B5 over the front point of contact *b* of relay 5SR and front contact *a* of relay 1C1TR5 to said terminal *f*. The No. 3 tone transmitter in unit 1CTT5 is, therefore, energized under this condition to transmit the high speed signal.

Output terminals *a* and *b* of transmitter unit 1CTT5 are connected to conductors 1RFC and BC4, respectively, and when relay 5SR is energized, the No. 1 tone transmitter in unit 1CTT5 modulates the carrier current from conductor 1RFC and supplies a first or low speed signal to conductor BC4. When relays 5SR and 1C1TR5 are both energized, No. 1 and No. 3 tone transmitters both modulate the carrier current from conductor 1RFC and

supply low and high speed signals to conductor BC4. Similarly, when relay SSR is released and relays 2C1TR5 and 2C2TR5 are energized, the No. 2 tone transmitter in unit 1CTT5 modulates the carrier current from conductor 1RFC and supplies a second or stick relay control signal to conductor BC4.

At Locs. 1 through 4 terminals *b* of transmitter units 1CTT1 through 1CTT4 are connected to block conductors BC0, BC1, BC2, and BC3, respectively, and terminals *a* of said transmitters are connected to conductor 1RFC. However, as previously indicated, terminal *a* of each location tone transmitter 1CTT will normally in practice be connected to terminal *a* of a local No. 1 carrier transmitter, similar to unit 1CT, rather than the conventionally shown conductor 1RFC. In view of the above description of the control circuits to unit 1CTT5, the control circuits to terminals *d*, *e* and *f* of units 1CTT1 through 1CTT4 need not be described in detail since these circuits are similar to those described for unit 1CTT5.

Referring to FIG. 1, it is pointed out that conductors 1RFC and BC0 are intended to extend to the next preceding location to the west of FIG. 1 to supply carrier transmitter energy from transmitter 1CT (FIG. 3) and control signals, respectively, to that westward location, and that these conductors are shown so extending merely to indicate that the system of my invention is applicable to a stretch of railway track of indefinite length and is not confined to the stretch of track shown in FIGS. 1 through 3. Similarly, at Loc. 5 conductors 1RFC and BC5 are shown extending east from Loc. 5 to the next succeeding location to the east of Loc. 5 in order that energy from transmitter 1CT may be supplied to the eastward locations not shown in the drawings, and in order that control signals may be received over conductor BC5 from the next eastward location. If, for some reason, there is difficulty experienced in understanding the system as shown, the track stretch shown may be assumed to comprise a circular railway and the conductors extending west from Loc. 1 may be assumed to connect to the corresponding conductors extending east from Loc. 5. The system will then be readily understood.

Having thus described the trackside apparatus of my invention, I will now describe the apparatus carried on each vehicle or train which traverses the track stretch shown in FIGS. 1 through 3. However, it should first be pointed out that the details of the train brake control apparatus and speed control apparatus shown in FIG. 4 form no part of my present invention, but are shown and described only to the extent necessary to make the specification complete.

A source of direct current such as a battery of proper voltage and capacity is required on each train for supplying energy for the operation of the train-carried apparatus. For purposes of simplicity, however, such source is not shown in FIG. 4 but its positive and negative terminals are designated by references VB and VN, respectively.

There is illustrated conventionally in FIG. 4 a carrier receiver R1CV and its associated antenna FANT connected to an input terminal *a* on the receiver. A second terminal *b* on the receiver is connected to ground in the usual manner. This carrier receiver is similar to carrier receivers R1C1 through R1C5 shown in FIGS. 1, 2 and 3, and is capable of receiving the basic No. 1 carrier current supplied to block conductors BC1 through BC5 (FIGS. 1, 2 and 3) and of providing an output which includes the first and third tones modulating the No. 1 carrier frequency supplied to said conductors. It will be readily understood that the receiver R1CV receives only such signals or tones supplied to the block conductor with which antenna FANT is at any one time closely coupled. In this connection it should be pointed out that antenna FANT corresponds to antenna FANT on vehicle V shown in FIG. 2. Terminal VN and terminal VB of the vehicle carried power source are connected to terminals *c* and *d*

of the receiver R1CV to provide energy for operation of the receiver.

Output terminals *e* and *f* on receiver R1CV are connected in multiple to input terminals *a* and *b*, respectively, on two tone or signal receivers designated No. 1 carrier-No. 1 tone receiver and No. 1 carrier-No. 3 tone receiver. Each such tone receiver is provided with output terminals *c* and *d* across which the winding of a relay is connected. The relay connected to terminals *c* and *d* of the No. 1 carrier-No. 1 tone receiver is a low speed control relay designated LSR, and the relay connected to terminals *c* and *d* of the No. 1 carrier-No. 3 tone receiver is a high speed control relay HSR. Each of the tone receivers shown in FIG. 4 is similar to the tone receivers R1C1T2 and R1C2T2 shown and described at Loc. 2 in FIG. 1 and each includes filter circuits that select only the signal or tone frequency of the respective receiver. Relays LSR and HSR are, therefore, energized only when their respective tone receiver receives current from carrier receiver R1CV of the correct tone frequency, that is, No. 1 tone and No. 3 tone, respectively. It is considered sufficient for purposes of this part of the description to point out that when one or both of such tone frequencies are transmitted over the first carrier current communication channel and are received by carrier receiver R1CV (FIG. 4), they are selectively received only by the corresponding tone receiver and the corresponding relay becomes energized.

It will be remembered that No. 2 carrier transmitter 2CT in FIG. 4 supplies No. 2 carrier frequency to conductor 2RFC. This carrier frequency is supplied from conductor 2RFC to input terminals *a* on No. 2 carrier-Nos. 1 and 2 tone transmitters designated 2C1TT and 2C2TT, respectively. Each of these transmitters may be similar to the No. 1 carrier tone transmitter 1CTT5 shown in FIG. 3 to increase apparatus interchangeability. However, since transmitter 2C1TT transmits only a No. 1 tone over carrier channel No. 2 and transmitter 2C2TT transmits only a No. 2 tone over carrier channel No. 2, these transmitters need not necessarily be similar to transmitter 1CTT5 but each may include only the required single tone transmitter. Output terminal *b* on transmitter 2C1TT is connected to antenna FANT on the vehicle and output terminal *b* on transmitter 2C2TT is connected to an antenna RANT on the vehicle. It will be understood that antenna RANT shown in FIG. 4 corresponds to antenna RANT on vehicle V shown in FIG. 2. Since, as stated above, transmitter 2C1TT transmits only No. 1 tone and transmits this tone continuously, terminal VB of the vehicle carried battery is connected only to a terminal *d* on the transmitter, such terminal corresponding to terminal *d* on transmitter 1CTT5 at Loc. 5. Similarly, since transmitter 2C2TT transmits only No. 2 tone and transmits this tone continuously, terminal VB of the battery is connected only to a terminal *e* on the transmitter, such terminal corresponding to terminal *e* on transmitter 1CTT5 at Loc. 5. Terminal VN of the vehicle carried battery is connected to a terminal *c* on each of the transmitters 2C1TT and 2C2TT, these terminals corresponding to terminal *c* on transmitter 1CTT5.

A brake valve control magnet BVM and an engine throttle control mechanism TCM are shown in FIG. 4 in block diagram form. As noted on the drawing, magnet valve BVM controls the release and application of the train brakes. That is, magnet BVM releases the train brakes when energized and applies the brakes when de-energized. Magnet valve BVM has a control circuit which extends from battery terminal VB over the front point of contact *b* of relay LSR and through the winding of the magnet valve to battery terminal VN. Magnet valve BVM is therefore energized and the train brakes become released whenever relay LSR is energized.

Throttle control mechanism TCM comprises two relays T1 and T2 which, when energized, actuate the throttle of the train to control the speed of the train to low and high

speeds respectively. One side of the control windings of relays T1 and T2 are connected in multiple to a terminal *c* on mechanism TCM, and the other side of the control windings of relays T1 and T2 connect to terminals *a* and *b*, respectively, on mechanism TCM. Terminal *c* of mechanism TCM is connected to battery terminal VN. The control circuit for relay T1 extends from terminal VB of the battery over front contact *a* of low speed relay LSR, the back point of contact *a* of high speed relay HSR, terminal *a* on mechanism TCM, the winding of relay T1, and terminal *c* on mechanism TCM to terminal VN of the battery. The control circuit for relay T2 extends from battery terminal VB over front contact *a* of low speed relay LSR, the front point of contact *a* of high speed relay HSR, terminal *b* on mechanism TCM, the winding of relay T2 and terminal *c* on mechanism TCM to terminal VN of the battery. Thus the speed of the train is controlled to a low speed when relays LSR and HSR are energized and deenergized, respectively, and to a high speed when both such relays are energized.

The train-carried apparatus of FIG. 4 is shown in the condition it assumes when the train on which it is provided is traveling at a high speed, that is, as if the apparatus shown was located on the train or vehicle V shown in FIG. 2 traveling through signal block TS4. For this reason relays LSR and HSR are both shown energized, and magnet valve BVM and relay T2 in mechanism TCM are also energized. Thus the train brakes are released and propulsion power is supplied to the train engine or motors by throttle control mechanism TCM to control the train to its high speed range. The controls for energizing relays LSR and HSR at this time will be covered hereinafter in operational examples of the apparatus of my invention. As previously mentioned, each of the trains or vehicles traversing the track stretch shown in FIGS. 1, 2 and 3 is provided with apparatus identical to that shown in FIG. 4.

I will now describe several operational examples of the apparatus of my invention. The apparatus at each of the Locs. 1 through 5 is shown under the conditions existing when vehicle V, occupying signal block TS4, is the only train in the track stretch shown, and there is no train in signal block TS5 (FIG. 3) nor in the next signal block to the east of block TS5. Under such conditions, relays 1C1TR5 and 5SR at Loc. 5 are energized, and relays 1C2TR5, 2C1TR5 and 2C2TR5 at that location are released. The reason for these positions of the relays will become apparent as the description proceeds.

Since, as pointed out above, relays 1C1TR5 and 5SR at Loc. 5 are energized, energy from battery terminal B5 is supplied to terminals *d* and *f* of transmitter 1CTT5, and that transmitter is supplying to block conductor BC4, No. 1 carrier-Nos. 1 and 3 tone signals. These signals are received by receiver R1C4 at Loc. 4, directly from conductor BC4, and the No. 1 carrier-No. 1 tone receiver R1C1T4 at Loc. 4 is energized to in turn energize relay 1C1TR4 at that location. However, the energization of relay 1C1TR4 performs no function at this time. The transmission of the No. 1 carrier-No. 3 tone does not at any time affect any apparatus at any of the Locs. 1 through 5, as will become apparent. The No. 1 and No. 3 tone signals are also received by antenna FANT and in turn receiver R1CV on vehicle V, and the No. 1 carrier-Nos. 1 and 3 tone receivers on the vehicle are energized to in turn energize relays LSR and HSR, respectively, as shown, train-carried transmitters 2C1TT and 2C2TT therefore, controlled to travel through signal block TS4 at its high speed range.

While vehicle V is traversing signal block TS4 as shown, train-carried transmitters 2C1TT and 2C2TT (FIG. 4) and antennas FANT and RANT are transmitting to block conductor BC4 the No. 2 carrier-Nos. 1 and 2 tones, respectively. These signals are received at Loc. 4 by carrier receiver R2C4, and tone receivers R2C1T4 and R2C2T4 are energized to in turn energize relays 2C1TR4 and 2C2TR4, respectively. As is apparent

relay 4SR is released under these conditions and energy from terminal B4 of the battery at Loc. 4 is being supplied to terminal *e* of No. 1 carrier tone transmitter 1CTT4. Transmitter 1CTT4 is thereby energized to transmit only No. 1 carrier-No. 2 tone to block conductor BC3.

At Loc. 3, since there is no vehicle in signal block TS3, relays 2C1TR3 and 2C2TR3 are released. The No. 1 carrier-No. 2 tone signal is being received at Loc. 3 by receiver R1C3 from conductor BC3, and receiver R1C2T3 and relay 1C2TR3 are energized. Relay 3SR at Loc. 3 is, therefore, in its picked up position and energy from terminal B3 of the battery at Loc. 3 is supplied to terminal *d* of No. 1 carrier tone transmitter 1CTT3 at Loc. 3. Transmitter 1CTT3 is thereby energized to transmit to block conductor BC2 the No. 1 carrier-No. 1 tone low speed signal only. It will be noted that should a second following vehicle pass Loc. 3 and enter signal block TS3 at this time, it will receive neither No. 1 nor No. 3 tone signal from block conductor BC3. Relays HSR and LSR on such vehicle will thus both be in a released position and the brakes of the vehicle will be applied.

At Loc. 2, at this time, relay 2SR is maintained picked up over its stick circuit and relay 1C1TR2 is energized due to the No. 1 carrier-No. 1 tone signal supplied to Loc. 3 to conductor BC2 and received at Loc. 2 by receivers R1C2 and R1C1T2. Energy from terminal B2 of the battery at Loc. 2 is, therefore, being supplied to terminals *d* and *f* of No. 1 carrier tone transmitter 1CTT2 at Loc. 2, and that transmitter is supplying the No. 1 carrier-Nos. 1 and 3 tones to block conductor BC1. It will be noted that should a vehicle enter signal block TS2 at this time, it will receive only No. 1 carrier-No. 1 tone speed signal from block conductor BC2 and the speed of such vehicle will then be controlled to its low speed range.

At Loc. 1 the apparatus is in the same condition as that described for Loc. 5 and no detailed description of the conditions of the apparatus at that location is necessary. However, it should be pointed out that should a vehicle, following vehicle V illustrated in FIG. 2, enter signal block TS1 at this time it will receive both the No. 1 carrier-Nos. 1 and 3 tone signals from conductor BC1 and will proceed through signal block TS1 at its high speed range. Upon entering signal block TS2, such vehicle would receive only the low speed signal, as pointed out above, and the speed of the vehicle would be reduced to its low speed range. As also previously pointed out, if such a vehicle continues into signal block TS3 at this time with no other condition change, it would receive no speed signal and its brakes would be applied to bring the vehicle to a stop. It is thus apparent that a "buffer" zone, approximately a signal block in length, is maintained behind vehicle V shown in FIG. 2, as well as any other vehicle to travel the track stretch.

The operation of the apparatus when vehicle V enters signal block TS5 will now be described. Upon the entrance of the front end of vehicle V and consequently antenna FANT into signal block TS5, the No. 2 carrier-No. 1 tone transmitter 2C1TT on vehicle V transmits that signal to block conductor BC5. This signal is received at Loc. 5 by receivers R2C5 and R2C1T5, and relay 2C1TR5 becomes energized. The energization of relay 2C1TR5 opens the stick circuit for relay 5SR and that relay releases and opens the energizing circuits to terminals *d* and *f* of transmitter 1CTT5. The transmission of signals to block conductor BC4 from transmitter 1CTT5 is thereby interrupted and relay 1C1TR4 at Loc. 4 is released. However, the release of relay 1C1TR4 at this time performs no function since the energizing circuit to terminal *f* of transmitter 1CTT4 (Loc. 4) is open at the front point of contact *b* of relay 4SR. It will be noted that the exit of the front end of vehicle V and consequently antenna FANT from signal block TS4 interrupts the transmission of No. 2 carrier-No. 1 tone to block conductor BC4 and relay 2C1TR4 at Loc. 4 is also

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released. The release of relay 2C1TR4 comprises a first of three steps in the closing of the pickup circuit for relay 4SR. The release of relay 2C1TR4 also opens the energizing circuit to terminal *e* of transmitter 1CTT4 (Loc. 4) and relay 1C2TR3 at Loc. 3 is released. The pickup circuit for relay 3SR at Loc. 3 is thus interrupted and, as is the normal condition, relay 3SR is now held energized only by its stick circuit.

When the front end of vehicle V enters signal block TS5, as set forth above, the receipt of speed control signals by antenna FANT from block conductor BC4 is, of course, terminated. However, antenna FANT immediately receives speed control signals from block conductor BC5 and relays LSR and HSR on the vehicle are maintained energized and the vehicle proceeds through signal block TS5 at its high speed range. The energization of relay 2C1TR5 and subsequent release of relay 5SR, described above upon the vehicle entering signal block, TS5, prepares an energizing circuit to terminal *e* of transmitter 1CTT5 which circuit is completed as described below.

It will now be assumed that the rear end of vehicle V and consequently antenna RANT exit from signal block TS4 and, of course, enter signal block TS5. The following operation of the apparatus then takes place.

The exit of antenna RANT from signal block TS4 terminates the transmission to conductor BC4 of No. 2 carrier-No. 2 tone signal and relay 2C2TR4 at Loc. 4 releases. The second of the aforesaid three steps in closing the pickup circuit for relay 4SR is completed by the closing of back contact *b* of relay 2C2TR4. The entrance of antenna RANT into signal block TS5 permits the transmission of No. 2 carrier-No. 2 tone signal to block conductor BC5 and relay 2C2TR5 (Loc. 5) becomes energized. The energization of relay 2C2TR5 completes the circuit for supplying energy to terminal *e* of transmitter 1CTT5, and No. 1 carrier-No. 2 tone is supplied to block conductor BC4. Relay 1C2TR4 at Loc. 4 is thereby energized and performs the third and last step in the closing of the pickup circuit for relay 4SR. Relay 4SR thereby becomes picked up and closes the energizing circuit to terminal *d* of transmitter 1CTT4 at Loc. 4. Transmitter 1CTT4 then supplies No. 1 carrier-No. 1 tone to block conductor BC3.

At Loc. 3, the No. 1 carrier-No. 1 tone signal received from block conductor BC3 energizes relay 1C1TR3 and energy is supplied to terminal *f* of transmitter 1CTT3. This transmitter then supplies No. 1 carrier-No. 3 tone signal to conductor BC2, as well as the No. 1 carrier-No. 1 tone signal previously being supplied to that conductor, and any vehicle following vehicle V and entering signal block TS2 would then be controlled to its high speed, whereas previously such following vehicle would have received a low speed signal only. No operation of the apparatus at Loc. 2 takes place at this time, however, since that apparatus was in its normal condition while vehicle V was traversing signal block TS4.

From the above description the manner in which the apparatus at each of the Locs. 1 through 5 operates, when a vehicle or vehicles provided with the train-carried apparatus of my invention travel over the track stretch, is believed readily apparent since each such set of apparatus operates in a similar manner, depending on the location of the vehicle or vehicles in the track stretch.

I have shown my invention as employing only two speed signals (No. 1 and No. 3 tones) but it is to be understood that additional higher speed ranges may be provided by employing an additional tone frequency and associated apparatus for each additional speed range.

Although I have herein shown and described only one form of apparatus embodying my invention, it should be 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.

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Having thus described my invention, what I claim is:

1. An automatic train operation system for a stretch of railway track over which trains travel in a single direction and including a series of locations in the stretch, each location defining the exit and entrance ends of preceding and succeeding signal blocks respectively, said system comprising, a signaling conductor for each said signal block extending the length of and parallel with the track of its respective signal block, signal transmitting means at each location for transmitting a plurality of distinct train control signals to the signaling conductor for the signal block preceding that location when a similar plurality of succeeding blocks are unoccupied by trains, signal receiving means on each train traveling said track stretch for receiving the train control signals transmitted to the signaling conductor for the signal block then occupied by the front end of the train, means on each train controlled by the signal receiving means on that train for controlling the speed of the train to a higher speed range in accordance with each additional train control signal received and for applying the brakes of the train when the receipt of such signals is interrupted, means at each location responsive to the occupancy of the succeeding signal block by the front end of a train for controlling the signal transmitting means at that location to interrupt the transmission of train control signals to the signaling conductor for the signal block preceding such location, means at each location responsive to the occupancy of the succeeding signal block by the rear end of a train for controlling the signal transmitting means at that location to transmit another distinct signal to the signaling conductor for the signal block preceding such location, signal receiving means at each location for selectively receiving the signals transmitted over the signaling conductor for the succeeding signal block, means at each location responsive to the receipt of said other distinct signal by the signal receiving means at that location for controlling the signal transmitting means at such location to interrupt the transmission of said other distinct signal and to transmit one of said train control signals to the signaling conductor for the signal block preceding such location, and means at each location responsive to the receipt of said one train control signal by the signal receiving means at that location for controlling the signal transmitting means at such location to transmit to the signaling conductor for the preceding signal block another of said train control signals in addition to said one train control signal.

2. An automatic train operation system for a stretch of railway track over which trains travel in a single direction, said system comprising, a plurality of locations in said track stretch each such location defining the exit and entrance ends of preceding and succeeding signal blocks respectively, an electrical block conductor for each said signal block each conductor extending parallel with and in close proximity to the track of said stretch, means at each said location for normally continuously supplying to the block conductor for the signal block for which such location is the exit end first and second distinct signals, first and second signal coupling devices on the front and rear ends respectively of each train to travel said track stretch each such device being so located on its respective end of its train as to be continuously in close proximity with the block conductor for the signal block through which that end of the train is then traveling, signal receiving means on each said train connected to said first signal coupling device on that train, means on each said train responsive to the receipt by said signal receiving means on that train of said first and second distinct signals for controlling the speed of the train and for applying the train brakes when the receipt of said first signal is interrupted, signal transmitting apparatus on each said train for supplying third and fourth distinct signals to said first and second signal coupling devices respectively, means at each said location in the track stretch

for receiving from the block conductor for the signal block for which such location is the entrance end said third distinct signal when the front end of a train occupies that block and said fourth distinct signal when the rear end of a train occupies the block, means at each said location responsive to the receipt of said third signal by the signal receiving means at that location for interrupting the supply of said first and second signals to the block conductor for the signal block for which such location is the exit end, means at each said location responsive to the receipt of said third and fourth signals by the signal receiving means at that location for supplying a fifth distinct signal to the block conductor for the signal block for which such location is the exit end, means at each said location for receiving from the block conductor for the signal block for which such location is the entrance end said fifth distinct signal when that signal is supplied to such block conductor, means at each said location responsive to the receipt of said fifth signal by said fifth signal receiving means at that location for again supplying said first signal to the block conductor for the signal block for which such location is the exit end, means at each said location for receiving from the block conductor for the signal block for which such location is the entrance end said first distinct signal when that signal is supplied to such block conductor, and means at each location responsive to the receipt of said first signal by said first signal receiving means at that location for again supplying said first and second signals to the block conductor for the signal block for which such location is the exit end.

3. An automatic train operation system for a stretch of railway track over which trains travel in a single direction and including a series of locations in the track stretch each location defining the entrance and exit ends of succeeding and preceding signal blocks respectively, said system comprising, an electrical block conductor for each signal block each conductor extending the length of and parallel with the track of its respective block, signal transmitting means at each location each for transmitting signals to the block conductor for the preceding signal block, signal receiving means at each location for receiving from the block conductor for the succeeding signal block selected signals transmitted to that conductor, means carried on each train for separately transmitting over the block conductor to the first preceding location signals indicating the occupancy of the signal block by the front end and the rear end of that train, means at each location responsive to the occupancy by the front end of a train of the succeeding signal block for controlling the signal transmitting means at that location to interrupt transmission of signals to the block conductor for the preceding signal block, means at each location responsive to the occupancy by the rear end of a train of the succeeding signal block for controlling the signal transmitting means at that location to transmit a first signal to the block conductor for the preceding signal block, means at each location responsive to the receipt of said first signal by the signal receiving means at that location for controlling the signal transmitting means at such location to interrupt transmission of said first signal and to transmit at least one other different signal to the block conductor for the preceding signal block, means at each location responsive to the receipt of said other signal by the signal receiving means at that location for controlling the signal transmitting means at such location to transmit to the block conductor for the preceding signal block the quantity of signals received at the location and another signal in addition, signal receiving means on each train traveling said track stretch for receiving said other signals transmitted to the block conductor for the signal block then occupied by the front end of such train, and means on each train actuated by the signal receiving means on that train for controlling the speed of the train to a higher speed range in accordance with each said

other signal received and for applying the brakes of the train when the receipt of such signals is interrupted.

4. A system for automatically controlling the movements of vehicles traveling a predetermined route, said route including a series of locations each location defining exit and entrance ends of preceding and succeeding route sections respectively, said system comprising, an electrical conductor extending between each location and the next succeeding location, signal transmitting means at each location, signal receiving means at each location connected to the electrical conductor extending to the next succeeding location for selectively receiving distinct signals from the conductor; means at each location controlled by the signal receiving means at such location for actuating the signal transmitting means at that location to transmit to the electrical conductor extending from the preceding location a first distinct signal when fourth and fifth distinct signals are received by such signal receiving means, a second distinct signal when said first distinct signal only is received by the signal receiving means, and said second and a third distinct signal when said second distinct signal is received by the signal receiving means following the receipt by such means of the first distinct signal; a signal receiving means on each vehicle to travel said route for receiving from the electrical conductor for the route section then being traveled by the vehicle said second and third distinct signals; means on each said vehicle controlled by said signal receiving means on such vehicle for controlling the speed of the vehicle to first and second speed ranges according as such signal receiving means receives only said second signal, or both said second and third signals, respectively, and for applying the brakes of the vehicle when the receipt of said second signal is interrupted; and means on each said vehicle for transmitting from the front and rear ends of such vehicle to the electrical conductor for the route section then being traveled by the vehicle said fourth and fifth signals, respectively.

5. A system for automatically controlling the movements of vehicles traveling a predetermined route, said route including a series of locations each location defining exit and entrance ends of preceding and succeeding route sections respectively, said system comprising, a signaling conductor extending between each location and the next succeeding location, first and second means on each vehicle to travel said route for transmitting first and second distinct signals respectively from the front and rear ends respectively of said vehicle to the signaling conductor for the route section in which each respective end of the vehicle is then traveling, signal receiving means at each said location for receiving signals from the signaling conductor extending to the next succeeding location; means controlled by the signal receiving means at each location for supplying to the signaling conductor extending from the next preceding location a third distinct signal when such signal receiving means receives both said first and second signals, a fourth distinct signal when such signal receiving means receives said third distinct signal, and said fourth and a fifth distinct signal when such signal receiving means receives a fourth distinct signal following the receipt of said third distinct signal; means on each said vehicle to travel said route for receiving from the signaling conductor for the route section in which the front end of such vehicle is then traveling said fourth and fifth distinct signals, and means controlled by the signal receiving means on each vehicle for controlling the speed of that vehicle to first and second speeds in accordance with the receipt of only said fourth signal and both said fourth and fifth signals, respectively, and for applying the brakes of the vehicle when the receipt of the fourth signal is interrupted.

6. An automatic train operation system for controlling the movements of trains traveling in a single direction over a stretch of railway track including a series of locations in the stretch each location defining the exit and

entrance ends of preceding and succeeding signal blocks respectively, said system comprising, an electrical block conductor for each signal block each such conductor extending parallel with and in close proximity to the track of its respective block; first, second, third and fourth relays at each location; signal receiving means at each location connected to the block conductor extending to the next succeeding location; means controlled by said signal receiving means at each location for energizing said first, second, third and fourth relays at that location according as that signal receiving means receives first, second, third and fourth signals respectively; signal transmitting means at each location each such means having its signal output connected to the block conductor extending to the next preceding location, a stick relay at each location; means controlled by the second, third and fourth relays at each location for energizing the stick relay at that location when the third and fourth relays are released and the second relay is energized; means controlled by the third and fourth relays at each location for maintaining the stick relay at that location energized when once energized and so long as the third and fourth relays remain released; means controlled by the stick relay at each location for actuating the signal transmitting means at that location to transmit said first signal when the stick relay is energized, means controlled by the stick relay and the first relay at each location for actuating the signal transmitting means at that location to transmit a fifth signal when the stick relay and the first relay are energized, means controlled by the stick relay and the third and fourth relays at each location for actuating

the signal transmitting means at that location to transmit said second signal when the stick relay is released and the third and fourth relays are energized, first and second antennas so located on the front and rear ends respectively of each train traveling said track stretch that each antenna is continuously coupled to the block conductor for the signal block which each respective end of each respective train is then traversing, a signal receiver on each said train connected to the antenna on the front end, means on each said train for continuously supplying to the first and second antennas on the train said third and fourth signals respectively, and means on each said train controlled by the signal receiver on the train for controlling the train to a low speed when said first signal only is received, to a high speed when both said first and fifth signals are received, and for applying the brakes of the train when the receipt of said first signal is interrupted.

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