United States Patent [19]

Matty

[11] **3,821,544**

[45] **June 28, 1974**

[54] **APPARATUS FOR SENSING POSITIONS OF VEHICLE ALONG A TRACK USING VOLTAGE SENSING IN CURRENT TRACK CIRCUITS**

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[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[21] Appl. No.: **274,696**

[52] **U.S. Cl.** .... **246/34 CT,** 246/36, 246/122 R

[51] **Int. Cl.** **B61l 21/00**

[58] **Field of Search** .... 246/34 CT, 36, 40, 63 R, 246/34 R, 122 R; 330/188

[56] **References Cited**

UNITED STATES PATENTS

1,919,064	7/1933	Hull	246/40
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1,066,355	4/1967	Great Britain	246/34 CT

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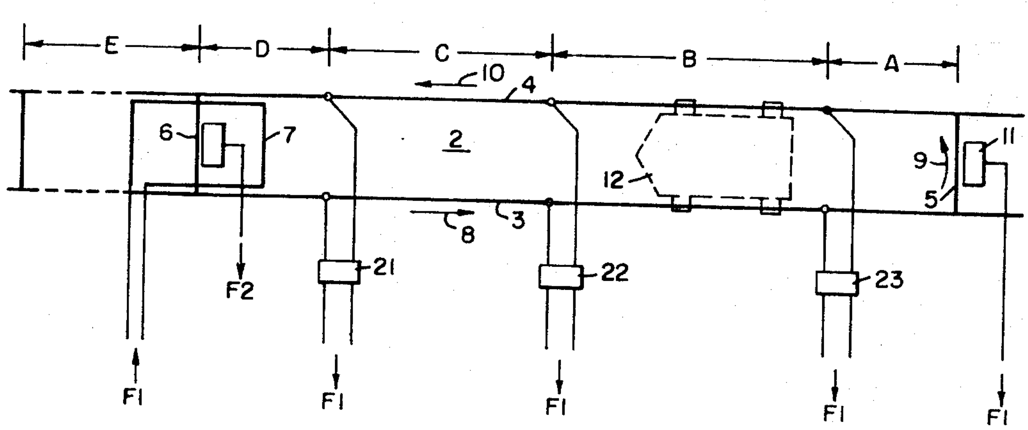
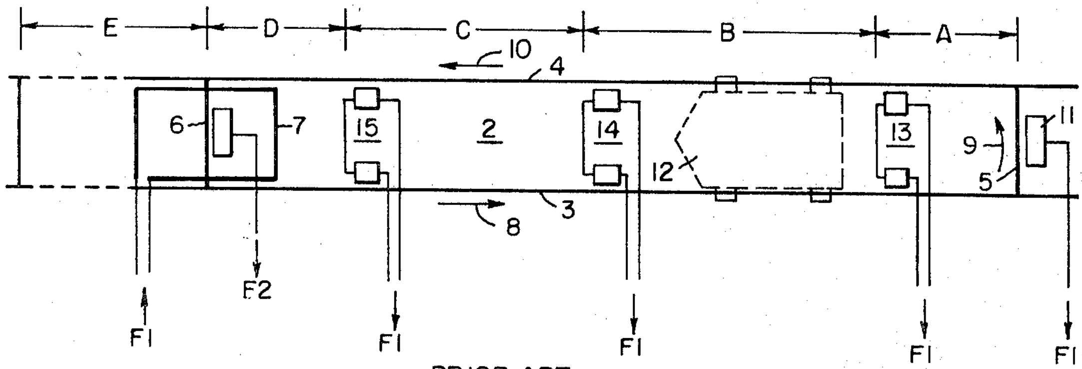
[57] **ABSTRACT**

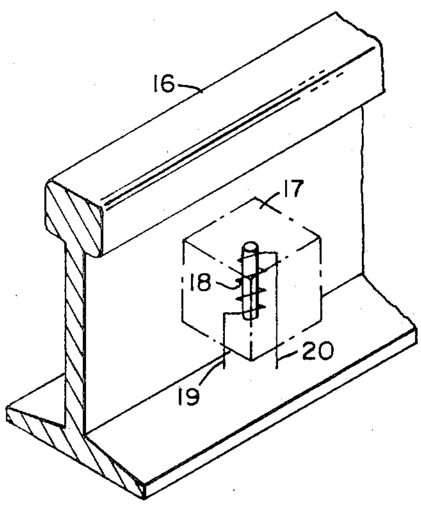
A vehicle control system in which a vehicle is operative on steel rails and in which a plurality of conductors are connected between the rails at predetermined locations. A track section between and including two such conductors forms a track circuit signalling block. At one end of the signalling block track current is introduced into the rails and a receiving antenna is positioned adjacent the conductor forming the other end of the track circuit signalling block. In the absence of a vehicle within the block, the receiving antenna senses a track current at a relatively high level and when a vehicle enters the track circuit signalling block the receiving means senses track current at a substantially reduced level. A plurality of voltage sensing means are located at predetermined locations across the track circuit signalling block for sensing the position of the vehicle within the signalling block. Each such voltage sensing means senses a voltage signal at a predetermined level in the absence of the vehicle being present adjacent the voltage sensing means. When the vehicle reaches a given voltage sensing means, the given voltage sensing means then senses voltage at a greatly reduced signal level which is indicative of the vehicle being present. Signal responsive means respond to the latter signal to provide an indication of vehicle presence at the given location.

4 Claims, 16 Drawing Figures





PRIOR ART
FIG. 1



PRIOR ART
FIG.2

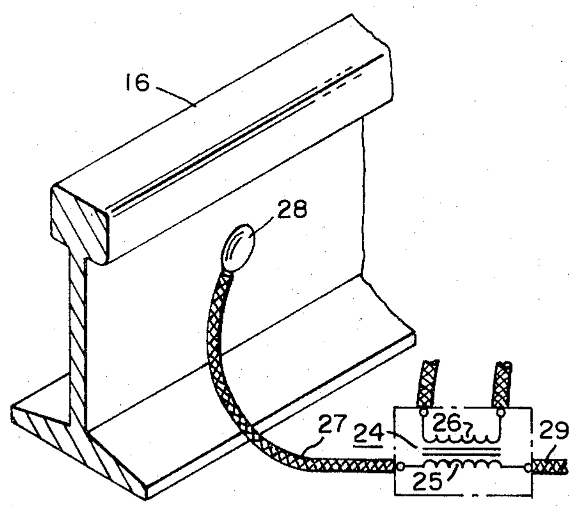


FIG.4

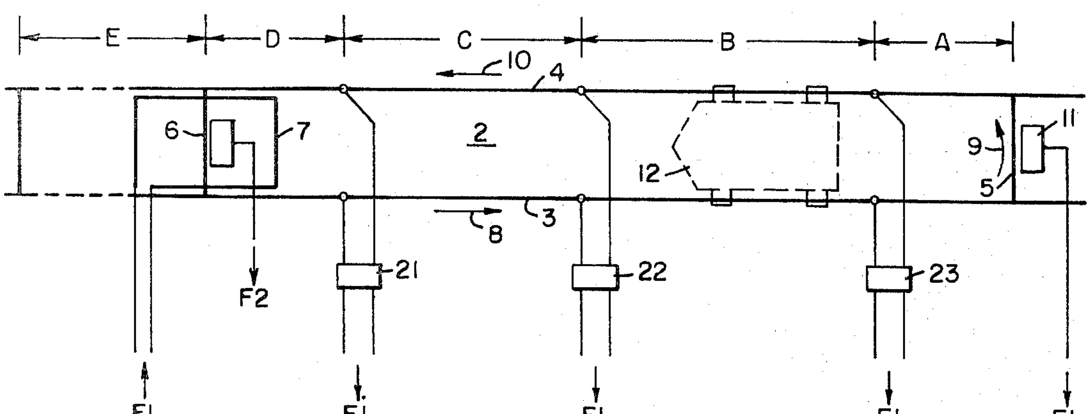


FIG.3

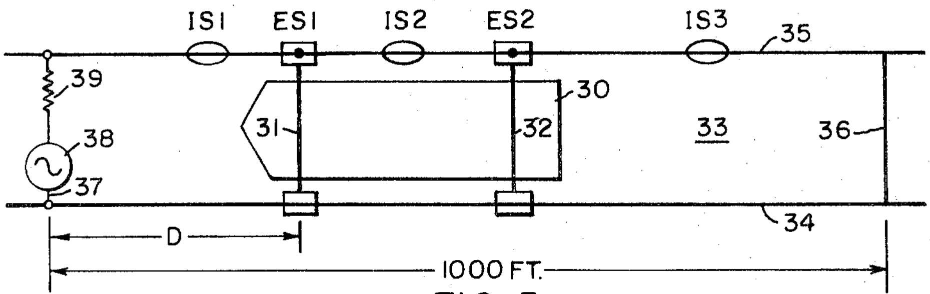


FIG. 5

ONE CAR VEHICLE IN 1000FT. BLOCK					
5KHZ(FREQ.)	OPEN	D=200FT.	D=100 FT.	D=50FT.	D=25FT.
ES1	.792 VOLT	.032 VOLT	.045 VOLT	.052 VOLT	.054 VOLT
ES2	.742 "	.005 "	.007 "	.008 "	.009 "
IS1	.068 AMP	.276 AMP	.388 AMP	.446 AMP	.465 AMP
IS2	.068 "	.043 "	.060 "	.070 "	.075 "
IS3	.068 "	001 "	001 "	.001 "	.001 "

FIG.6

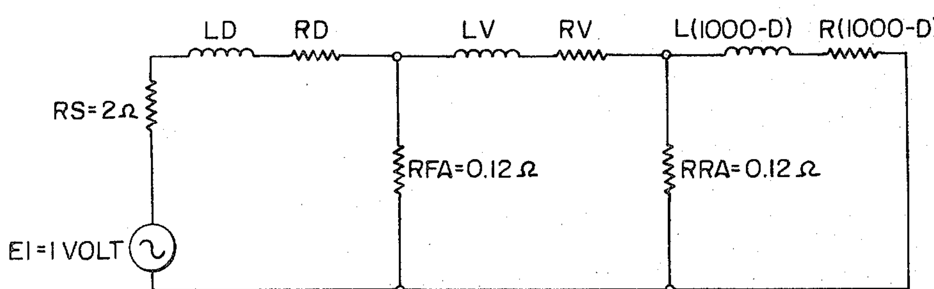


FIG.7

ONE CAR VEHICLE IN 1000 FT. BLOCK (IMPEDANCE VALUES)							
D	LD	RD	LV	RV	1000-D	L(1000-D)	R(1000-D)
25	11.625×10^{-6}	300×10^{-6}	23.25×10^{-6}	600×10^{-6}	925	430×10^{-6}	11100×10^{-6}
50	23.250×10^{-6}	600×10^{-6}	23.25×10^{-6}	600×10^{-6}	900	418×10^{-6}	10800×10^{-6}
100	46.500×10^{-6}	1200×10^{-6}	23.25×10^{-6}	600×10^{-6}	850	395×10^{-6}	10200×10^{-6}
200	93.000×10^{-6}	2400×10^{-6}	23.25×10^{-6}	600×10^{-6}	750	348×10^{-6}	9000×10^{-6}

FIG.8

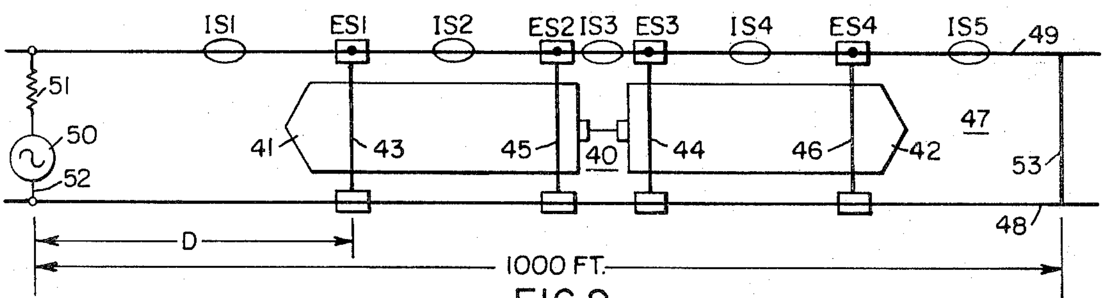


FIG.9

TWO CAR VEHICLE IN 1000 FT. BLOCK					
5KHZ(FREQ)	OPEN	D=200 FT.	D=100 FT.	D=50 FT.	D=25 FT.
ES1	.791 VOLT	.058 VOLT	.080 VOLT	.092 VOLT	.095 VOLT
ES2	.741 "	.015 "	.021 "	.024 "	.025 "
ES3	.691 "	.004 "	.005 "	.006 "	.006 "
ES4	.641 "	.001 "	.002 "	.002 "	.002 "
IS1	.068 AMP	.269 AMP	.373 AMP	.427 AMP	.447 AMP
IS2	.068 "	.071 "	.099 "	.113 "	.118 "
IS3	.068 "	.019 "	.026 "	.030 "	.031 "
IS4	.068 "	.005 "	.007 "	.008 "	.008 "
IS5	.068 "	.0001 "	.0002 "	.0002 "	.002 "

FIG.10

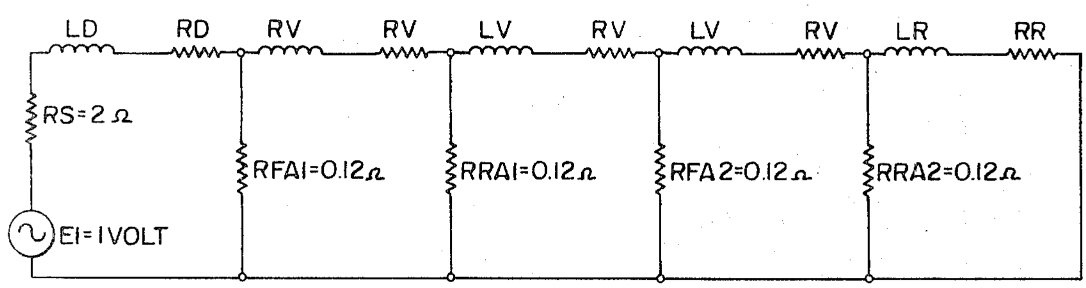


FIG.11

TWO CAR VEHICLE IN 1000 FT. BLOCK (IMPEDANCE VALUES)							
D	LD	RD	LV	RV	1000-D	LR	RR
25	11.625×10^{-6}	300×10^{-6}	23.25×10^{-6}	600×10^{-6}	825	385×10^{-6}	9900×10^{-6}
50	23.250×10^{-6}	600×10^{-6}	23.25×10^{-6}	600×10^{-6}	800	370×10^{-6}	9600×10^{-6}
100	46.500×10^{-6}	1200×10^{-6}	23.25×10^{-6}	600×10^{-6}	750	349×10^{-6}	9000×10^{-6}
200	93.000×10^{-6}	2400×10^{-6}	23.25×10^{-6}	600×10^{-6}	650	300×10^{-6}	7800×10^{-6}

FIG.12

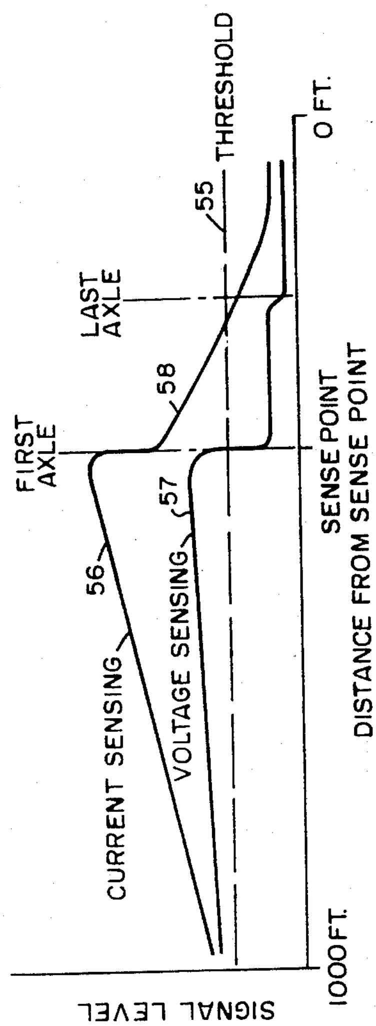

SIGNAL LEVEL
THRESHOLD
55
56
57
58
FIRST AXLE
LAST AXLE
CURRENT SENSING
VOLTAGE SENSING
0 FT.
1000 FT.
SENSE POINT
DISTANCE FROM SENSE POINT

FIG. 13

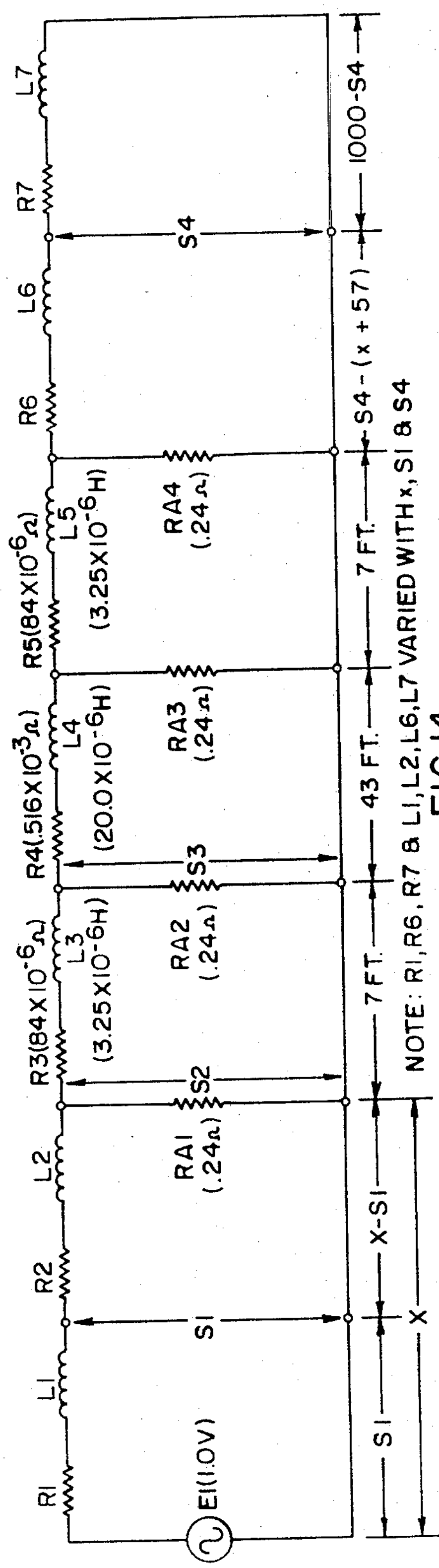

E1(1.0V)
R1
L1
R2
L2
R3(84X10^-6 Ω)
L3 (3.25X10^-6H)
R4(.516X10^-3 Ω)
L4 (20.0X10^-6H)
R5(84X10^-6 Ω)
L5 (3.25X10^-6H)
R6
L6
R7
L7
RA1 (.24Ω)
RA2 (.24Ω)
RA3 (.24Ω)
RA4 (.24Ω)
S1
S2
S3
S4
S1
X-S1
X
7 FT.
43 FT.
7 FT.
S4-(x+57)
1000-S4
NOTE: R1, R6, R7 & L1, L2, L6, L7 VARIED WITH x, S1 & S4

FIG. 14

DISTANCE OF FRONT AXLE FROM TRANSMITTER	DISTANCE OF SENSE POINT FROM TRANSMITTER					
	6 FT.	25 FT.	53 FT.	240 FT.	400 FT.	760 FT.
BLOCK UNOCCUPIED	.994	.975	.947	.760	.600	.240
900 FT.	.993	.972	.941	.732	.557	.159
800 "	–	–	–	–	–	.0546
770 "	–	–	–	–	.483	.0202
760 "	–	–	–	.684	–	.0120
753 "	.992	.967	.930	–	–	.0098
693 "	–	–	–	–	–	.00178
500 "	–	–	–	–	.205	–
410 "	–	–	–	–	.0378	–
400 "	–	–	–	.560	.0167	–
393 "	.985	.937	.866	–	.0187	–
333 "	–	–	–	–	.00380	.00152
300 "	–	–	–	.209	–	–
250 "	–	–	–	.0614	–	–
240 "	–	–	.782	.0377	–	–
233 "	.974	.894	–	.0314	–	–
173 "	–	–	–	.00729	.00575	.00231
100 "	–	.760	.492	–	–	–
63 "	–	–	.235	–	–	–
53 "	–	.568	.162	–	–	–
46 "	.881	–	.149	–	–	–
35 "	–	.401	–	–	–	–
25 "	.807	.312	–	–	–	–
18 "	.762	.326	–	–	–	–
16 "	.748	–	–	–	–	–
6 "	.844	–	–	.0846	.0668	.0268

FIG. 15

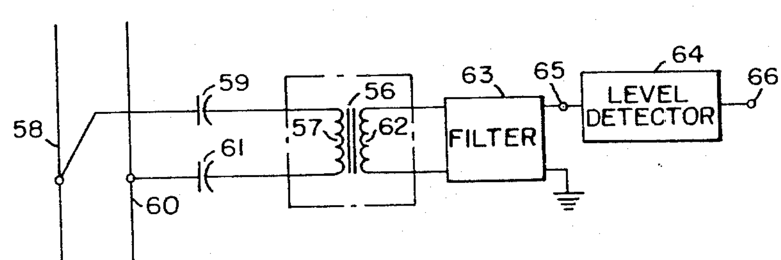


FIG. 16

APPARATUS FOR SENSING POSITIONS OF VEHICLE ALONG A TRACK USING VOLTAGE SENSING IN CURRENT TRACK CIRCUITS

CROSS REFERENCE TO RELATED APPLICATIONS

Reference is made to U.S. Pat. No. 3,526,378 entitled "Signalling System for Determining the Presence of a Train Vehicle," filed Aug. 23, 1967 on behalf of G.M. Thorne-Booth; and U.S. Pat. No. 3,657,663 entitled "AC Threshold Amplifier for Use in Failsafe Applications," filed May 27, 1970 on behalf of R. S. Rhoton et al, which application is a continuation of now abandoned patent application Ser. No. 752,870, filed Aug. 14, 1968. Each of the above-named issued U.S. patents, and the now abandoned U.S. patent application is assigned to the assignee of the present invention.

BACKGROUND OF THE INVENTION

In a vehicle control system in which a vehicle travels along a vehicle travel path which is divided into a plurality of track circuit signalling blocks, there is a need to know when a vehicle is present in a given track circuit signalling block. Vehicle presence must be detected such that other vehicles are not allowed to enter the given track circuit signalling block, thereby preventing a collision. There is also a need to know the precise position of a vehicle within a given track circuit signalling block such that the vehicle, for example, may be stopped at an interlock such as a gate, or at a station. Since a vehicle is usually comprised of a plurality of vehicle cars it is necessary to know when the first such vehicle car is present at a given sensing position. This was not possible in the prior art, since the presence of a vehicle was not readily known until all or at least most of the vehicle cars had passed a given point, the reason being that in the prior art track current which was introduced into the rails was sensed. The current sensed near a transmitter or on the order of up to 400 feet or so from the transmitter instead of decreasing in response to a vehicle being present, increased to a certain degree which caused ambiguity as to the exact physical location of the vehicle. The sensed current did not drop to a predetermined threshold level until all or at least most of the vehicle cars had passed the sense point. This clearly is a non-safe condition since a vehicle which is comprised of a large number of cars may have the first cars thereof enter into a non-safe condition or even a collision prior to the following vehicle cars passing the sense point.

According to the teachings of the present invention a vehicle position sensing system is disclosed wherein the sense points are comprised of voltage sensing means positioned across the rails such that when the first of a plurality of vehicle cars reaches the sense position the sense voltage drops to a level below a predetermined threshold level thus indicating the exact position of the vehicle.

SUMMARY OF THE INVENTION

According to the teachings of the present invention a system is disclosed for determining the position of a vehicle within a signal conductive signalling block comprised of a conductive track including a pair of conductive continuous rails. There are means connected between said rails at predetermined locations for providing respective signal conduction paths between the rails, with each track section between and including the respective signal conduction paths defining one of the signal conductive signalling blocks. Also included are means for introducing a signal into the rails of a given signalling block. Further includes is at least one signal responsive means located between the rails at a predetermined location within the given signalling block, for sensing the introduced signal when the vehicle is not present at the predetermined location, and for sensing the introduced signal at a reduced signal level when the vehicle is present at the predetermined location.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram representation of a track circuit signalling block including intermediate position sensing means, according to the teachings of the prior art;

FIG. 2 is a diagrammatic illustration of how an intermediate position sensing means is physically attached to a rail which forms part of a track circuit signalling block, according to the teachings of the prior art;

FIG. 3 is a schematic diagram representation of a track circuit signalling block including intermediate position sensing means, according to the teachings of the present invention;

FIG. 4 is a diagrammatic representation of how a voltage sensing means is attached to a rail of a track circuit signalling block, according to the teachings of the present invention;

FIG. 5 is a schematic diagram representation of a vehicle comprised of one vehicle car within a vehicle control block which includes a plurality of current and voltage sense points within the track circuit signalling block;

FIG. 6 is a table giving values of the voltages and currents sensed at the sense points illustrated in FIG. 5;

FIG. 7 is a schematic diagram representation of the model used in computing the voltage and currents at the respective sense points in the track signal circuiting block illustrated in FIG. 5;

FIG. 8 is a table which gives the impedance values of the various circuit elements in the model of FIG. 7;

FIG. 9 is a schematic diagram representation of a track circuit signalling block in which two vehicle cars are present and which includes a plurality of voltage and current sense points within the track circuit signalling block;

FIG. 10 is a table which gives the values of the voltages and currents sensed at the respective sense points in the circuit of FIG. 9;

FIG. 11 is a schematic diagram representation of the model used in computing the voltage and currents at the respective sense points in the circuit of FIG. 9;

FIG. 12 is a table which gives the impedance values of the various circuit elements in the model of FIG. 11;

FIG. 13 is a graphical representation of the voltage and current sensed in a track circuit signalling block relative to the distance of a vehicle from a given sense point;

FIG. 14 is a schematic diagram representation of the model used in computing the voltages sensed in a track circuit signalling block at various sense points when a one vehicle car vehicle is present at different positions within the signalling block;

FIG. 15 is a table of values of the voltages sensed at various positions within a track circuit signalling block as derived from the model illustrated in FIG. 14; and

FIG. 16 is a schematic diagram representation of a voltage responsive intermediate position signal sensing means and associated signal level detecting means according to the teachings of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As was previously discussed, the prior art intermediate position sensing devices sense current flowing in the rails of a track circuit whereas according to the teachings of the present invention the voltage between the rails is sensed to determine the position of a vehicle within a track circuit signalling block.

Refer now to FIG. 1 which illustrates a track circuit signalling block of the prior art as disclosed in the previously referenced U.S. Pat. No. 3,526,378. One track circuit signalling block 2 is illustrated in which a conductive track is comprised of a pair of conductive continuous rails 3 and 4. There are means connected between the rails at predetermined locations for providing respective signal conduction paths such as the conductors or short-circuit members 5 and 6. A signal transmitting antenna 7 receives a signal at a frequency F1 from a transmitter (not shown) which introduces track current at frequency F1 into the rails 3 and 4 in a direction through the track circuit signalling block 2 as is illustrated by the arrows 8, 9 and 10 respectively. A signal receiving means 11 is situated at the end of the track circuit signalling block defined by the conductor 5. In the absence of a vehicle within the track circuit signalling block the receiving means 11 senses a signal at the frequency F1 which in indicative of the absence of a vehicle within the track circuit signalling block. When a vehicle such as the vehicle 12 enters the signalling block the axles of the vehicle 12 act as shunts and short the current flowing in the tracks 3 and 4 such that essentially no current at frequency F1 is sensed by the receiving means 11. Intermediate the conductors 5 and 6 which form the boundaries of the track circuit signalling block 2 are intermediate position current sensing means 13, 14 and 15. These sensing means are responsive to the current flowing in the rails 3 and 4 for giving an indication of the position of a vehicle within the track circuit signalling block. It is to be appreciated that a plurality of track circuit signalling blocks (not shown) are connected to the right and left of signalling block 2.

FIG. 2 illustrates how the intermediate position sensing means is physically attached to a rail. For example, a section of rail 16 has a member 17 attached thereto which includes a coil or receiving antenna 18. It is seen, in reference to FIG. 1, that one conductor such as the conductor 19 is connected to a similar coil or antenna on the other rail, while the lead 20 is attached to a receiving means (not shown).

Return now to FIG. 1. As will be explained shortly, as a vehicle approaches one of the intermediate position sensing means the current flowing through the track circuit increases since the impedance the antenna sees decreases. This is true since the voltage induced into the rail by the transmitting antenna is constant. Since the impedance the antenna see decreases, it follows that the track current must increase. Therefore, the voltage produced in the antenna of an intermediate position sensing means such as the means 13 increased. This is true since $E = jwMI_p$, when M is the mutual inductance between the rail and the coil and I_p is the current in the rails. Therefore, it is an ambiguous indication as to the exact position of the vehicle until the vehicle passes or has substantially passed the intermediate position sensing means whereby the current decreases and therefore the sensed voltage also decreases. The increase in current is most clearly noted within 400 feet or so of the signal transmitter. As the vehicle 12 approaches the signal receiving means 13 the sensed current rises slightly and remains essentially at the same level as each vehicle car passes the sensing means 13. The current does not drop to a significantly low value until all or at least most of the vehicle cars comprising the vehicle 12 pass the current sense means 13. The same condition exists as the vehicle 12 approaches, reaches, and then passes the current sense means 14 and 15. As was previously explained this ambiguity in sensed current results in a non-safe condition. If the vehicle 12 is comprised of a plurality of vehicle cars and the vehicle for example is to stop at a gate or a station or within a predetermined distance from same, the need for accurate position sensing becomes readily apparent.

Refer now to FIG. 3 which discloses an intermediate position sensing embodiment according to the teachings of the present invention. Like elements in FIG. 3 are given the same numerical designation as like elements in FIG. 1, the difference being in FIG. 3 that voltage responsive means are connected between or across the track rails 3 and 4 at predetermined locations for accurately sensing the position of the vehicle 12 within the track circuit 2. These voltage responsive position sensing means are the devices 21, 22 and 23 which will be described in greater detail shortly. As was previously explained, as the vehicle 12 proceeds from right to left as illustrated in FIG. 3 the track current flowing in the rails ahead and through the axles of the vehicle increases since the impedance seen by the signal antenna 7 decreases due to the current shunting effect of the vehicle axles. Therefore, if one is to measure the voltage between the track rails the voltage sensed will remain at substantially constant level as the first vehicle car approaches the sense point, and then drop to a threshold level when the sense point is reached. As each successive vehicle car passes over the sense point, the voltage sensed remains at or below the threshold level thereby giving an indication that the vehicle is present at the sense position.

Refer now to FIG. 4 which is schematic diagram representation of how the voltage sensing means is attached to the rail 16. The voltage sensing means for example may be a transformer 24 having a primary winding 25 and a secondary winding 26. One terminal of the primary winding 25 is connected by means of a conductor 27 to the rail 16 by a suitable fastening means such as a press pin 28. The remaining terminal of the primary winding 25 is connected by means of a conductor 29 to the other rail (not shown) by a suitable fastening means. The secondary winding 26 is connected to a suitable signal receiving means or level detector (not shown). Therefore, the voltage induced in the primary winding 25 connected between the rails of the track circuit produces a voltage across the secondary winding 26 and the signal receiving means responds to the drop in voltage as an indication of the presence of a vehicle. This will be described in greater detail shortly. As was previously stated, when a vehicle enters a given vehicle control block the current in the vehicle control block increases ahead of the vehicle and decreases behind the vehicle. Therefore ambiguity exists as to the exact position of the vehicle, when using current sensing, until all or at least most of the vehicle cars pass the point, On the other hand, as has been previously stated, when a vehicle enters a vehicle control block the voltage sensed between the tracks at a position adjacent the front axle of the vehicle the voltage decreases thereby giving a more precise indication of the location of the vehicle. The reason the voltage remains substantially constant across the transformer and drops only a small amount as the vehicle approaches the sense point is due to the high input impedance of the transformer as compared with the low impedance of the axle shunt. The transformer, therefore, draws negligible current with respect to the current drawn through the rails and the axle shunt. When the axle is adjacent the transformer, however, the voltage across the transformer drops since the impedance at the sense point is the parallel impedance of the transformer and the axle, which is essentially the axle impedance.

Refer now to FIGS. **5** through **8** which show through the use of models, why the aforementioned statements are correct.

In FIG. **5** a vehicle **30** having axles **31** and **32** is shown traveling in a track circuit signalling block **33** comprised of a pair of continuous conductive rails **34** and **35** with a conductor **36** defining one end of the track circuit signalling block **33** and the other conductor **37** shown with a voltage source **38** and a source resistance **39** indicating schematically the short circuit member and its associated transmitting antenna. The track circuit signalling block is chosen to be one thousand feet in length and the distance from the front axle **31** of the vehicle to the signal source **38** is depicted by the symbol D. Various voltage and current sense points are indicated by the symbols **ES1**, **ES2**, **IS1**, **IS2** and **IS3**, respectively. It is to be appreciated that the voltage sense points (ES) are between the tracks **34** and **35** as measured across the axles of the vehicle. The sense point IS1 is always directly ahead of the vehicle; the voltage sense points ES1 and ES2 are always across the axles **31** and **32** respectively, except for the instance when the track circuit signalling block is open, that is, a vehicle is not present within the block. In this instance, ES2 is measured between the tracks **34** and **35** at an arbitrary distance from the entrance end of the block, and ES1 is measured between the tracks at a distance from the sense point ES2 approximately equal to the distance between the respective axles of the vehicle; the current sense point IS2 is always directly beneath the vehicle; and the current sense point IS3 is always directly behind the vehicle. The vehicle is assumed to be a one car train in a one thousand foot block. The signal source **38** is assumed to be a one volt voltage source operating at a frequency of 5 KHz.

The table in FIG. **6** shows the values of the sensed voltages and currents with the distance (D) from the transmitter from 200 feet to 25 feet in the track circuit signalling block. It is seen with the track circuit signalling block open, that is, a vehicle not being present within the track circuit signalling block, that IS1 is at a value of 0.068 amps. When the distance (D) is 200 feet, IS1 increases to a value of 0.276 amps, and finally increases to a value of 0.465 amps when the distance D reaches 25 feet. Terefore, it is readily seen that the current IS1 ahead of the vehicle increases as the vehicle enters the vehicle control block. On the other hand, the voltage ES1 which is measured across the front axle of the vehicle, which would be the point at which a vehicle is first sensed by a fixed voltage sensing means across the track that the voltage decreases when the vehicle enters the vehicle control block. When the vehicle control block is open, that is a vehicle is not present, the voltage ES1 is 0.792 volts. At a distance D = 200 feet, the voltage drops to a value of 0.032 volts, which is a substantial drop in voltage from the open condition. From a sense point of 200 feet to a sense point of 25 feet the voltage ES1 rises slightly to a value of 0.054 volts which is only a change of 0.022 volts which can be assumed to be substantially constant.

The voltage and current values found in the table of FIG. **6** were derived from the model schematic set forth in FIG. **7** wherein the voltage source **E1** and the source resistance RS are the equivalents of the signal transmitting antenna. The inductor LD and the resistor RD are equivalents of the impedance of the track circuit directly ahead of the vehicle. The resistance element RFA is the resistance of the front axle of the vehicle. The inductor LV and the resistor RV are the equivalent of the track impedance directly beneath the vehicle. The resistor RRA is indicative of the impedance of the back axle of the vehicle. The inductor L(**1000-D**) and the resistor R(**1000-D**) are equivalents of the track impedance behind the vehicle to the short circuit member or conductor forming the boundary of the track circuit signalling block. The table in FIG. **8** sets forth the impedance values of the above-named impedance elements for the different positions D of the vehicle as measured from the source of voltage **E1**. It is readily apparent to one skilled in the art of linear circuit analysis how the current and voltage values found in the table of FIG. **6** are derived from the circuit of FIG. **7** using the impedance values found in the table of FIG. **8**. A standard text on linear circuit analysis is "Linear Circuits" by Ronald E. Scott, copyright 1960 by Addison-Wesley Publishing Company, Inc.

The ambiguity produced in current sensing in a track circuit signalling block is also true for a multi-vehicle car vehicle. This is shown in reference to FIGS. **9** through **12** which set forth the schematic circuit diagram for a two vehicle car and the attendant model and model impedance values and voltage and current tables similar to those set forth for the one car vehicle illustrated in FIG. **5**.

In FIG. **9**, a two vehicle car **40** is comprised of vehicle cars **41** and **42** which have front axles **43** and **44** and rear axles **45** and **46** respectively. The vehicle car **40** travels in a track circuit signalling block **47** comprised of continuous conductive rails **48** and **49**. A voltage source **50** and its source resistance **51** are equivalent of the transmitting antenna present across the short circuit member **52** which forms one boundary of the track circuit signalling block **47** is defined by the conductor **53**. Again, the track circuit signalling block is assumed to be 1,000 feet in length and the distance D from the front axle of the vehicle **41** is varied in the analysis. The various sense points are set forth as current sense points IS1, current head of the vehicle; IS2, current under vehicle car **41**; IS3, current between the vehicle cars **41** and **42**; IS4, current directly beneath the vehicle car 42; and IS5, current behind the vehicle 40. Voltage is again sensed between the rails across the axles of the vehicles. ES1 is the voltage sensed between the rails at the axle 43; ES2 is the voltage sensed between the rails at the axle 45; ES3 is the voltage sensed between the rails at the axle 44; and ES4 is the voltage sensed between the rails at the axle 46; except for the instance when the track circuit signalling block is open, that is, a vehicle is not present within the block. In this instance ES4 is measured between the tracks 48 and 49 at an arbitrary distance from the entrance end of the block and ES3, ES2 and ES1 are measured between the tracks at distances from ES4 approximately equal to the distances between the respective axles of the vehicle. In the absence of a vehicle in the vehicle control block 47, the current IS1 is 0.068 amps (See FIG. 10). When a vehicle enters the vehicle control block and is sensed at a distance D= 200 feet from the source 50 the current IS1 increases to a value of 0.269 amps and thereafter increases to a value of 0.447 amps at the point D = 25 from the source. Again, it is seen that the current increases when a vehicle enters the vehicle control block and does not decrease until the vehicle has completely or at least nearly passed the sense point (see IS4 and IS5 in FIG. 10). On the other hand, the voltage ES1 is 0.791 volts in the absence of a vehicle in the vehicle control block, which voltage drops to 0.058 volts when the vehicle enters the control block and is sensed at the distance D = 200 from the source. This voltage (ES1) increases a slight amount to a level of 0.095 volts when the vehicle front axle reaches the point distance D = 25 from the source.

The model set forth in FIG. 11 is a schematic diagram representation of the two car vehicle present in the one thousand foot vehicle control block of FIG. 9. The resistances RFA1 and RRA1 are the front and rear axle impedance respectively of the vehicle car 41. The resistances RFA2 and RRA2 are the impedances of the front and rear axles respectively of the vehicle car 42. The inductance LD and resistance RD are the impedance values ahead of the vehicle. The inductance LR and the resistance RR are the impedance of the track circuit behind the vehicle. The inductance LV and resistance RV are the track circuits impedances directly underneath and between the two vehicle cars. The voltage source E1 and the source resistance RS are indicative of the signal transmitting antenna voltage and impedance values respectively.

FIG. 12 sets forth the impedance values of the above-named impedance elements of FIG. 11 for various distances (D) from the source, for deriving the signal level set forth in the table of FIG. 10. From the above set forth data, it should be readily apparent that voltage sensing is superior to the current sensing of the prior art for distances within 400 feet or so of the signal transmitter. This will be more clear from what follows.

FIG. 13 is a graphical representation showing representative signal levels when using voltage sensing as opposed to current sensing. A threshold level for sensing is shown by a dashed line 55. It is seen that the current sensed, as shown by the current sensing curve 56, increases in magnitude as the vehicle travels from the farthest point from the sense point to the actual sense point. When the first axle of the vehicle reaches the sense point, the signal level of the current sensed drops to a lower value. It is seen however that the current sensed is not of a value sufficiently low to reach the threshold level, which is indicative of a vehicle presence. On the other hand, referring to the voltage sensing curve 57 it is seen that the voltage sensed remains essentially constant and at a lower level than the current sensing curve until the first axle reaches the sense point. The voltage sensed then drops to a signal level below the threshold, indicating a vehicle is present. When or slightly before the last axle of the vehicle passes the sense point, the signal level from the current sensing means then drops below the threshold level. The slope 58 of the curve 56 varies dependent on the number of vehicle cars used. It is therefore very difficult to determine the precise point when the threshold will be reached when using current sensing. On the other hand, the voltage sensing curve gives a more precise indication of the position of the vehicle when the first axle passes the sense point, and continues to do so until the last axle of the vehicle passes the same point. This is more readily seen in reference to FIG. 15 which is a table of voltage values measured at fixed sense points relative to a signal transmitter as a vehicle travels through a signalling block.

In referring to FIG. 15 the portion of the table with the heading "Distance of Sense Point From Transmitter" shows fixed sense points of 6 feet (6'), 25 feet (25'), — 760 feet (760') where sense points are located. A "distance of the front axle from the transmitter" (see leftmost column in FIG. 15) is then measured and readings are taken at the various fixed sense points as a vehicle traverses through a given track circuit signalling block block. Consider first the sense point which is 240 feet from the signal transmitter. With no vehicle in the signal block (first row of leftmost column of FIG. 15), a signal voltage of 0.760 volts is registered by the sense means located 240 feet from the transmitter. When the vehicle is 900 feet from the transmitter, a voltage of 0.732 volts is measured at the sense means located 240 feet from the transmitter. When the vehicle is 400 feet from the transmitter, the sense means located at 240 feet registers 0.560 volts. It is seen that the voltage is decreasing somewhat but is however still at a substantially low and constant level. As the vehicle nears the 240 feet sense point for example 300 feet from the source, the voltage drops to 0.209 volts, and at 250 feet from the source to 0.0614 volts, and 240 feet from the source (the sense point) to 0.0377 volts. It is seen therefore that the signal receiving means connected to the sense means at 240 feet may have a threshold set somewhere on the order of 0.03 to 0.06 volts and the presence of the vehicle at the sense point can readily be sensed since the initial voltage signal sensed was 0.760 volts which then slowly dropped until it reached the 0.06 volt level at approximately 250 feet from the transmitter. It is readily seen from referring to other portions of the table that there is an appreciable drop in voltage as the vehicle approaches a given sense point. Also, for each sense point the voltage threshold to be sensed is adjusted for a different voltage level. For example, at the 53 foot sense point it is seen that the voltage sensed when the vehicle is present at the 53 foot sense point is on the order of 0.162 volts. Therefore the threshold could be set anywhere from on the order of 0.160 to 0.180 volts to give a clear indication of the vehicle presence.

The model in FIG. 14 is the model used to derive the voltage sense points values found in the table of FIG. 15. The impedance of the front axles of the vehicle are denoted by the resistances RA1 and RA2, respectively, and the impedance of the back axles of the vehicle are denoted by the resistances RA3 and RA4, respectively. The other impedance elements shown in the model correspond to the like impedance elements illustrated in the models of FIGS. 7 and 11, respectively.

Refer now to FIG. 16 which illustrates a voltage responsive signal sensing means which may be used as the voltage sensing means shown in FIG. 3, and which may take the form of a transformer 56 which has a primary winding 57 having one terminal connected to a track rail 58 by way of a coupling capacitor 59 and the remaining terminal of the primary winding 57 connected to the other track rail 60 by way of a coupling capacitor 61. The secondary winding 62 of the transformer 56 is connected to a filter 63 which is tuned to the track circuit signal frequency in question. The output of the filter 63 is then connected to a suitable threshold amplifier and level detector such as the previously referenced threshold amplifier described in U.S. Pat. No. 3,657,663. The threshold amplifier and level detector 64 has its input 65 connected to the output of the filter 63. A signal output is provided at an output terminal 66 in response to a predetermined signal voltage level being provided to the input 65 of the level detector 64. This signal level being indicative of a vehicle being adjacent the sense point. As was previously stated, the input impedance of the transformer is chosen to many times higher than the impedance of the rails and the axle shunts such that the transformer draws a negligible amount of current as compared with the current flowing through the rails and the axle shunts.

In summary, a system has been disclosed for determining the position of a vehicle within a signal conductive signalling block comprised of a conductive track including a pair of conductive continuous rails. A plurality of conductors are connected between the pair of rails at predetermined locations for providing a signal conductive path between the rails, with the track section between and including two such conductors defining one of the signalling blocks. There are also means included for introducing track current into the rails of the given signalling block, and there is further included at least one voltage responsive means connected between the rails at a predetermined location within the signalling block for sensing voltage a at a selected voltage level in response to the absence of the vehicle at the predetermined location, and for sensing voltage at a level below the selected voltage level in response to the presence of the vehicle at the predetermined location.

I claim as my invention:

1. In a system for determining the position of a vehicle within one of a plurality of signal conductive signalling blocks comprised of a conductive track including a pair of conductive continuous rails, the combination comprising:

a plurality of conductors, with one such conductor being connected between said rails at each of a plurality of predetermined locations, each of said conductors providing a signal conductive path between said rails, with a track section between and including two such conductors forming one of said signalling blocks;

means for introducing a signal current into each of said signalling blocks;

at least one signal voltage responsive means connected between said rails at a predetermined location in a given one of said signalling blocks for sensing signal voltage between said rails at said predetermined location at a given level in the absence of a vehicle in said one signalling block and for sensing a decrease in signal voltage to a minimum voltage level as said vehicle approaches said predetermined location, with said one voltage responsive means having a high impedance relative to the impedance of said rails such that essentially all of said signal current flows through said rails and a negligible amount of said signal current flows through said one signal voltage responsive means, with said decrease in signal voltage to a minimum voltage level as said vehicle approaches said predetermined location being caused by the low impedance of the axles of said vehicle reducing the impedance between said rails at said predetermined location.

2. In a system for determining the position of a vehicle within one of a plurality of signal conductive signalling blocks comprised of a conductive track including a pair of conductive continuous rails, the combination comprising:

a plurality of conductors connected between said rails at selected locations for providing respective signal conduction paths between said rails, with a track section between and including two such conductors defining one of said signalling blocks;

means for introducing current into a given signalling block;

a plurality of voltage responsive means connected between said rails at predetermined locations within said given signalling block for sensing voltage between said rails at each of said predetermined locations, the voltage sensed at a given one of said predetermined locations decreasing from a maximum to a minimum voltage level as said vehicle approaches said given one of said predetermined locations, with each of said voltage responsive means having a high impedance relative to the impedance of said rails such that essentially of said signal current flows through said rails and a negligible amount of said signal current flows through any of said voltage responsive means, with the decrease in voltage sensed at said given one of said predetermined locations being caused by the low impedance of the axles of said vehicle reducing the impedance between said rails at said given one of said predetermined locations.

3. The combination claimed in claim 2, wherein each of said voltage responsive means includes a transformer having a primary winding connected between said rails, and also having a secondary winding.

4. The combination claimed in claim 3 wherein said voltage responsive means further includes:

a filter having an input connected to the secondary winding of said transformer, and also having an output; and

a level detector having an input connected to the output of said filter, and also having an output at which an output signal is provided in response to a signal of at least a given value being applied to said input.

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