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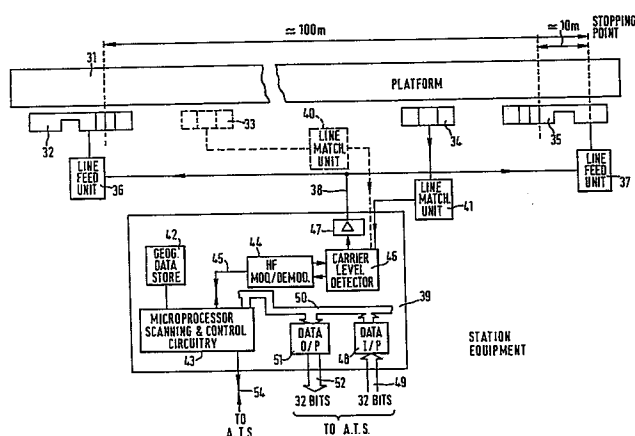
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54 **Automatic railway vehicle operation.**

57 There is disclosed an automatic driving system for a railway vehicle. In a permanent way, there is means for substantially continuously communicating to a vehicle signalling information which concerns safety of movement. At a station, there is means (39, 32, 35) for periodically supplying a vehicle with static information (such as gradients, distances between stops and target arrival times) concerning efficient operation of the vehicle. On each vehicle there are: means (2) for receiving the signalling information; means (14) for receiving and means (20) for storing the static information; and means (4) for measuring the speed of the vehicle and distance it has travelled; and control means (8) capable of producing control outputs (10, 9) to operate the brakes and the motors of the vehicle in accordance with inputs produced in response to the stored static information and the received signalling information.



AUTOMATIC RAILWAY VEHICLE OPERATION

This invention relates to a system for automatic railway vehicle operation.

5 Driverless automatic trains are operated using the same basic signalling principles as employed for manually driven trains, that is, the train is driven as if it has a clear line ahead until it begins to infringe the minimum safe headway distance to the rear of another train, whereupon vehicle speed is reduced
10 and eventually it may be halted.

In addition to conventional headway safety signals, visual or electrical, an automatic train may receive signals representing an absolute maximum speed limit and a target speed limit. The train is then
15 driven to attempt to maintain the target speed without exceeding the maximum speed. Thus, when it begins to approach the minimum headway of a train ahead the target speed is reduced and the train's brakes are actuated immediately to slow the train to its target
20 speed. The train control equipment is supplied with at least one service braking profile and, similarly, at least one service acceleration profile. The target speeds are computed by a central traffic controller which is responsible for controlling the operation of
25 a complete network or a complete section of the network involving the conflicting movements of many trains over many routes.

An object of the present invention is to provide an automatic train with a degree of "intelligence" so
30 that it can calculate its own acceleration, braking, and speed profiles taking into account more detailed information of the immediate route to be traversed.

According to the invention there is provided an automatic driving system for a railway vehicle
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comprising, in a permanent way, means for substantially continuously communicating to a vehicle signalling information which concerns safety of movement; means for periodically supplying a vehicle
5 with static information (such as gradients, distances between stops and target arrival times) concerning efficient operation of the vehicle; and on each vehicle, means for receiving the signalling information; means for receiving and storing the
10 static information; means for measuring the speed of the vehicle and distance it has travelled; and control means capable of producing control outputs to operate the brakes and the motors of the vehicle in accordance with inputs produced in response to the stored static
15 information and the received signalling information.

Preferably, at a station there is provided means for transmitting the static information to the vehicle, this information being transferred to the vehicle while it is standing at the station, and
20 stored in the storing means on the vehicle. Stored static information received at one station may be replaced by fresh static information received at the next station at which the vehicle stops.

The invention will now be described, by way of
25 example only, with reference to the accompanying drawings in which:

Fig.1 is a schematic illustration of a train carried operating apparatus;

Fig.2 is a schematic illustration of automatic
30 train operating equipment in Fig.1;

Fig.3 is a schematic illustration of fixed equipment at a station;

Fig.4 shows in schematic form an arrangement of a station ground loop for accurate train stop control;

and

Fig.5 shows comparative train speed profiles, with and without the invention.

Referring firstly to Fig.1, the illustrated
5 apparatus comprises an automatic train protection
(A.T.P.) equipment 1 connected to receive a first input
from a pick-up 2. This pick-up 2 may comprise an
inductive loop antenna mounted underneath the train,
low down at the front of the leading bogie, ahead of
10 the leading axle, and in close proximity to one of the
track rails 3.

Electrical currents induced in the track rails 3 in
the form of track circuit signals are sensed by the
pick-up 2. The signals are used, firstly, by track
15 circuit equipment (not shown) to detect the presence of
a train in the track section between the equipment's
transmitter and receiver apparatus. This is well known
in the art and well described elsewhere. As it is
really only of background interest as far as the
20 present invention is concerned, it will be assumed that
the reader is familiar with the technology.

The pick-up 2 is duplicated. The second pick-up is
identical with the first but is mounted close to the
other rail. Both pick-ups are connected to provide a
25 track circuit signal input to the A.T.P. equipment 1.

The apparatus being described makes use of A.C.
coded signals used to modulate the basic track circuit
signal carrier frequency for train operating purposes.
The coded signals impressed on the track circuit
30 carrier signal convey maximum speed and target speed
information to a train. This speed information, in
effect, replaces the information given to a human
driver by means of the conventional coloured light
signalling equipment. Briefly, it works as follows. The

train is given a maximum speed which it must not exceed and a target speed which may be expected to be its maximum speed in the next section. Target speeds may be progressively lowered in stages in successive
5 sections down to zero. Equal maximum and target speeds are equivalent to a conventional green coloured light; a target speed lower than maximum speed is equivalent to a warning amber coloured light; and a zero target speed is the same as a red aspect stop signal.

10 The train carried A.T.P. equipment 1 could be of a form known in the art - see for example British Patent Specifications Nos. 2159311 and 2017991. The maximum and target speed coded signals are contained in a code modulated track circuit signal transmitted through the
15 track rails 3 and received via pick-ups 2. This signal is decoded by the equipment 1 in order to extract the speed limit information. The actual speed of the train is measured by a tachometer 4 which generates an electrical output signal proportional to
20 the speed of the train. This speed output signal is connected to a second input of the A.T.P. equipment 1.

The A.T.P. equipment is operative to compare the measured train speed signal from tachometer 4 with the maximum speed limit signal decoded from the modulated
25 track circuit signal received via pick-ups 2. If the measured speed exceeds the maximum speed limit the brakes are applied automatically by the A.T.P. equipment 1. The equipment 1 has an emergency brake control output 5 connected to the brake system. When
30 the emergency brake signal appears on output 5 the train's brakes are automatically applied to emergency braking level. The A.T.P. equipment 1 has two further outputs 6 and 7 which carry, respectively, the target speed signal and the track circuit frequency.

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Automatic train operating (A.T.O.) equipment is represented by block 8 in Fig.1. This comprises a micro-processor system which will be described in more detail below. The A.T.O. equipment 8 has two control
5 outputs 9 and 10 which are operatively connected to control the train's motor control and brake systems respectively. The target speed and track circuit frequency signal outputs 6 and 7 from the A.T.P.
10 equipment 1 are connected respectively to inputs 11 and 12 of the A.T.O. equipment 8. A further A.T.O. input 13 is connected with another duplicated inductive loop antenna receiving arrangement, indicated by reference numeral 14.

The A.T.O. equipment 8 also has an output line 15
15 which is connected to a duplicated transmitter loop antenna arrangement, indicated by reference 16. The antenna arrangements 14 and 16 are mounted underneath the vehicle containing the A.T.O. equipment, to inductively couple with loops laid in the track bed in
20 close proximity to the track rails 3, and they are installed further back on the vehicle than the pick-ups 2 referred to above. The measured speed signal from tachometer 4 is connected to an input 17 to the A.T.O. equipment 8.

25 Fig.2 shows the A.T.O. equipment in greater detail, parts also shown in Fig.1 having like references. The central part of the A.T.O. equipment is a micro-processor 18. The operation of processor 18 is controlled by data instructions, i.e. operating
30 programs, stored in a programmable read only memory (PROM) 19 comprising a control data store connected to the processor. Also connected to the processor 18 is a further memory 20 which acts as a geographical data store.

The processor 18 has an input 21 and an output 22 which are connected through a high frequency carrier modulator/demodulator block 23 to the duplicated receiver and transmitter antennae 14 and 16. The
5 signal to the transmitter antennae is boosted by an amplifier 24. Received and transmitted signals are modulated high frequency carrier signals, the output from the duplicated antennae 14 being applied to the block 23 via a carrier level detector 25. The block
10 23 includes a matching high frequency signal generator and, also, circuits which modulate a carrier signal with the processor output 22 for transmission, and which demodulate a received modulated carrier signal and pass the modulation signal to the processor input
15 21.

Processor 18 is also connected to a system data bus 26 for two way communication with a data input block 27, a data output block 28 and a distance/velocity measurement unit 29. The input and output blocks 27 and
20 28 carry the train operating system control signals. The processor 18 is housed in a demountable unit and is connected into the normal train control circuits through an interface 30. The control outputs 9 and 10 for the motors and brakes emerge from the processor 18
25 through interface 30, and the target speed and track circuit frequency signals on inputs 11 and 12 enter the processor 18 through the interface 30.

The tachometer 4 is connected to the distance/velocity measurement unit 29, this unit
30 comprising a further micro-processor based unit operating independently of the main processor 18. The tachometer 4 may comprise an a.c. generator producing an analogue signal, the frequency of which is directly proportional to the speed of rotation of the vehicle
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wheels and, therefore, to the speed of the vehicle. The unit 29 includes a squaring circuit which produces a digital logic compatible signal from the tachometer analogue output. The micro-processor is programmed to process this signal to provide a distance measurement, that is, the distance travelled by the train from an initial point, by counting the number of pulses generated, to provide a velocity measurement by determining the rate of change with time of the distance movement; and to provide an indication of movement in reverse (runback).

The measurement unit 29 provides its output in a digital format compatible with the input word format of processor 18. The output of unit 29 is connected with the data bus 26.

Fig.3 illustrates in block diagram form the fixed equipment part of the system installed at a station halt. A station platform is indicated in outline at 31 and adjacent to this platform is a railway track (not shown) in the body of which are located several loop aerials 32,33,34 and 35 of two types. The loops 32 and 35 of the first type are positioned about 100 metres apart towards opposite ends of the platform. Their construction is shown in greater detail in Fig.4. More particularly their electrical configuration which is drawn at Fig.4(b) is of special interest and will be referred to below in more detail.

The loops 33 and 34, which are of the second type, are located between the positions of the loops 32 and 35. The loop 33 is shown by dashed lines to indicate that it is an optional feature. In practice the embodiment utilises only three of the four loops at any one time, as dictated by the direction of travel of a train. In Fig.3, a train is assumed to move from left

to right in the plane of the page, so that it uses the loops 32, 34 and 35. The loops 34 and 35 are positioned reasonably close together and at the stopping position of the head of the train. For a
5 train travelling in the opposite direction, the embodiment uses the loops 32, 33, 35, the loops 32 and 33 being positioned reasonably close together and at the head of the train.

The loops 32 and 35 of the first type are used to
10 transmit data to a train. A train moving from left to right is halted with its receiving antennae 14 accurately positioned above the portion of the loop 35 referenced A in Fig.4. A train travelling in the opposite direction is halted with the receiving
15 antennae 14 above the portion A of the loop 32.

The transmitter loops 32 and 35 are connected to an output 38 from a "Platform Communicator Unit" 39 via line feed units 36 and 37 respectively; and the loops
20 33 and 34 are connected to the unit 39 via line matching units 40 and 41 respectively. The platform communicator unit 39 includes: a geographical data store 42; micro-processor based scanning and control circuitry 43 for scanning the store 42 so that the latter may be selectively read and its data transmitted
25 to the train via loop 35 if the train is moving from left to right and via loop 32 if the train is moving from right to left in Fig.3; high frequency carrier modulating/demodulating circuitry 44 coupled via a bi-directional link 45 to the circuitry 43; carrier
30 level detector circuitry 46 having inputs connected to outputs of line matching units 40 and 41, an output connected to an input of circuitry 44, an input connected to an output of circuitry 44 and an output
35 connected via a power amplifier 47 to output 38 of the

unit 39; data input circuitry 48 coupled via a parallel interface bus 49 with an automatic train supervisory (A.T.S.) facility in a traffic control office and via a data bus 50 to circuitry 43; data output circuitry 51
5 coupled via a parallel interface 52 with the A.T.S. facility and via data bus 50 to circuitry 43; and a twisted-pair bi-directional link 54 coupled between the circuitry 43 and the A.T.S. facility.

The geographical data in store 42 describes the
10 next stretch of track, extending as far as the next station halt. This data comprises gradient information, data describing junctions and crossings, track section lengths, track section carrier operating frequencies, maximum speed limits, train schedule
15 information and the like, or any other data which must be taken into account to operate a train most efficiently. Data sent to data input circuitry 48 via interface 49 and/or data sent to circuitry 43 via link 54 includes digitally coded information describing
20 current signalling information, i.e. temporarily imposed maximum speed limits and current target speed limits for each track section along the route to the next station. This information is provided from the A.T.S. facility. This information is therefore
25 dependent on, for example, the presence of another train on the same track in order to maintain a minimum safe headway distance.

The fixed geographical data from store 42 and the transient signalling data received by circuitry 48
30 and/or via link 54 are encoded, as a series of digital data telegrams which are fed to circuitry 44 under the control of circuitry 43 via link 45. A high frequency carrier signal generated by circuitry 44 is frequency modulated in circuitry 44 using the digital telegrams
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as modulation signals. The resultant modulated signal is then fed into the loop 32 or 35 via detector circuitry 46, power amplifier 47, output 38 and unit 36 or 37. The "handshake" signal transmitted from the train and received by loop 34 is supplied through line matching unit 41 to the carrier level detector circuitry 46. The circuitry 46 stores a value representing the maximum level of signal received when the train first traverses the loop 32 or 35. When subsequently the signal reduces in level, the data presented to circuitry 43 via line 45 is switched off when the level reaches a fixed percentage of the maximum level stored.

The construction of each of the loops 32 and 35 is shown in more detail in Fig.4(b). Each loop has an overall length of 15 metres and comprises several sub-loops indicated by the reference letters A, B, C, D and E. The divisions between sub-loops B, C, D and E are formed by cross-overs. As a pair of train antennae pass over these cross-overs, when the loop is energised, the signal received by the train experiences a pronounced fall in level followed by a rise as shown in Fig.4(c). The cross-over division between sub-loops B and C is positioned approximately 10 metres from the required stopping point of the train, which is arranged to be within sub-loop A. The corresponding level variations in the train received signal may therefore be used as distance calibration points by the train on-board processor 18, and also as low speed checks. This enables the train to be halted precisely with receiving antennae 14 over sub-loop A in loop 35 and antennae 16 over loop 34 if the train is travelling from left to right in Fig.3. A train travelling in the

opposite direction uses loops 32, 33 and 35 in the same way but halts with its antennae 14 and 16 positioned over loops 32 and 33 respectively.

5 The sequence of events, as a train approaches the station shown in Fig.3 and from the left is as follows. The train has already been driven under the command of the A.T.O. equipment in accordance with the signalling system's maximum and target speed limits, and the
10 A.T.O. equipment's controls are attempting to halt the train with its head as close as possible to the stopping point (see Fig.3).

The Platform Communicator Unit 39 is in its standby mode, continuously transmitting synchronisation data to the loops 32 and 35. This data may comprise a single
15 tone signal but preferably comprises a frequency shift keyed signal containing a station identity code. As the antennae 14 on the train pass over loop 32, the two become inductively coupled and the processor 18 on the train receives a corresponding input. The rectified
20 signal level of the input follows the signal curve shown at Fig.4(c), but traced from right to left. The second crossover point, between the sub-loops C and D in Figs. 4(a) and (b), is designated as a first synchronisation point. It is located at approximately
25 100 metres from the stopping point. At the first synchronisation point, the processor 18 acts to synchronise the distance/velocity measurement unit 29, and selects the appropriate brake control signal required by the braking profile needed to stop the
30 train in the required position. Some time later, the train begins to pass over the second transmitting loop 35. As the antennae 14 pass over the third cross-over, that is between sub-loops C and B in Figs. 4(a) and (b) and moving left to right, the processor 18 recognises a
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second synchronisation point. This point is 10 metres from the stopping point and is employed as a final check and up-date, if necessary, of the braking requirement.

5 When the train has halted, the antennae 14 are directly above the area A of loop 35, and antennae 16 are directly above loop 34. The unit 29 indicates zero speed and, in response to this, the processor 18 triggers the transmission of a "wake-up" message and
10 its identity code via antennae 16 to the platform communicator unit 39. Having thus established two-way communication, the unit 39 begins to transmit its predetermined data messages.

15 The first such message may be an instruction to open the doors of the train. Also, if the platform has edge screen doors, these are opened at the same time. In the latter case it is absolutely essential that the train shall have been brought to rest very accurately with the train doors in register with the screen doors,
20 and the multiple point synchronisation pattern described above will ensure this. Next, the unit 39 transmits the geographical data and the signalling data to the train.

25 The new geographical data is loaded into memory 20 to replace the old geographical data, which is now discarded. Preferably, while this is taking place the train continues to transmit its identity code to the unit 39. This is a "continuous handshake" and continues throughout the station dwell time. At
30 the end of this period, the unit 39 ceases data transmissions and the A.T.O. equipment re-closes the doors.

35 When the train doors and platform screen doors, if any, are closed, an indication is passed to the A.T.O.

equipment on the train in preparation for restarting the train's journey. A fully automatic train may move off in response to this indication. On a train having a human "driver" or supervisor it may be necessary for him to verify a start command, e.g. by pressing a start button or the like.

As the train progresses along the track, the pick-ups 2 mounted underneath the front of the train receive coded track circuit signals from the rails 3 and the A.T.P. equipment passes speed information and track circuit frequency to the A.T.O. equipment 8. The tachometer 4 generates output pulses from which unit 29 is able to indicate speed and distance travelled to the A.T.O. equipment 8. The processor 18 under the control of the program stored in memory 19, performs two basic tasks. Firstly, it determines where the train is by comparing the distance travelled from the last stopping point and the frequency of the track circuit carrier signal with the geographical data stored in the memory 20. This technique is more fully described in the co-pending Patent Application No. 86310164-8 entitled "Positive Route Identification". Having identified its present location, the processor 18 then reads from memory 20 geographical data describing the route or trackway ahead of the train. In order to calculate the speed at which the train should be travelling and particularly a current acceleration rate, deceleration rate or if the train should be coasting, the processor must take into consideration track gradient, maximum track speed limit, and distance to the next speed change, i.e. the lengths of the track sections. Fig.5 illustrates one respect in which this allows a train to be operated with greater efficiency.

In Fig.5 a train is assumed to be travelling from

left to right, the vertical dashed lines indicating the boundaries between adjacent track sections. The vertical scale at the left of the drawing indicates train speed in kilometres per hour (kph), and on the abscissa are shown the track section speed codes as maximum speed over target speed, the target speed being the maximum speed to be achieved on entry to the next section. As shown, the speed codes, from the left, are 80/80, 80/65, and 65/65. The train enters from the left at roughly 80 kph. When it enters the second section, the target speed is reduced to 65 kph. In a conventional system this reduction would immediately trigger the A.T.O. equipment 8 to apply the brakes to reduce speed to just under 65 kph and this is illustrated by the curve labelled "without invention". The presently described equipment is able to continue for longer without braking because the processor 18 is able to read the length of the second track section from the geographical data store. This enables it to calculate the nearest point to the end of the section at which braking must be commenced, taking into account not only the length of the section but also track gradient. This is represented by the speed curve labelled "with invention". The braking point and running speed may also be selected according to the running times compared with schedule times. For example, if a train has time in hand compared to schedule time then it need not be driven up to the maximum speed limit, and braking may be commenced according to the time difference in hand, or a train may be driven to comply with a speed restriction several sections ahead, and recorded in the fixed data, even though the maximum and target speeds in intervening sections may be higher.

CLAIMS

1: An automatic driving system for a railway vehicle comprising:-

- 5 a) in a permanent way, means for substantially continuously communicating to a vehicle signalling information which concerns safety of movement;
- b) means for periodically supplying a vehicle with static information concerning efficient operation of the vehicle; and
- 10 c) on each vehicle:-
 - i) means for receiving the signalling information;
 - ii) means for receiving and means for storing the static information;
 - 15 iii) means for measuring the speed of the vehicle and distance it has travelled; and
 - iv) control means capable of producing control outputs to operate the
 - 20 brakes and the motors of the vehicle in accordance with inputs produced in response to the stored static information and the received information.

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2. A system according to Claim 1, wherein said means on each vehicle for receiving and storing the static information comprise:-

- 30 a) antenna means for receiving the static information; and
- b) data storage means for storing the static information under the control of a micro-processor, the control means of the vehicle including said micro-processor.

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3. A system according to Claim 1 or 2, wherein said means for periodically supplying a vehicle with static information comprises means at a station for transmitting the static information to the vehicle while the vehicle is
5 standing at the station, the information being stored in the storing means on the vehicle.

4. A system according to Claim 3, wherein stored static information received at one station is replaced by
10 fresh static information received at the next station at which the vehicle stops.

5. A system according to Claim 3 or 4, wherein said means at a station comprises:-
15 a) data storage means for storing static information;
b) means for detecting arrival of a vehicle at the station; and
c) means for causing the static information to be
20 transmitted via the transmitting means to the vehicle while the latter is standing at the station.

6. A system according to Claim 5, wherein said
25 detecting means comprises loop means for detecting inductively arrival of a vehicle at the station.

7. A system according to Claim 5 or 6, wherein said means at a station further comprises means for scanning
30 said data storage means at the station so that the information in the data storage means may be selectively transmitted to a vehicle at the station.

8. A system according to any of Claims 5, 6 and 7,
35 wherein said means at a station further comprises means for communicating with remote supervisory means for indicating to the latter arrival of a vehicle at the station.

9. A system according to Claim 8, wherein said means at a station is such that transient signalling information received by said communicating means from said supervisory means is transmitted via the transmitting means to a vehicle while the latter is standing at the station.

10 A system according to any of Claims 3 to 9, wherein said transmitting means at a station comprises loop means for transmitting inductively information to a vehicle.

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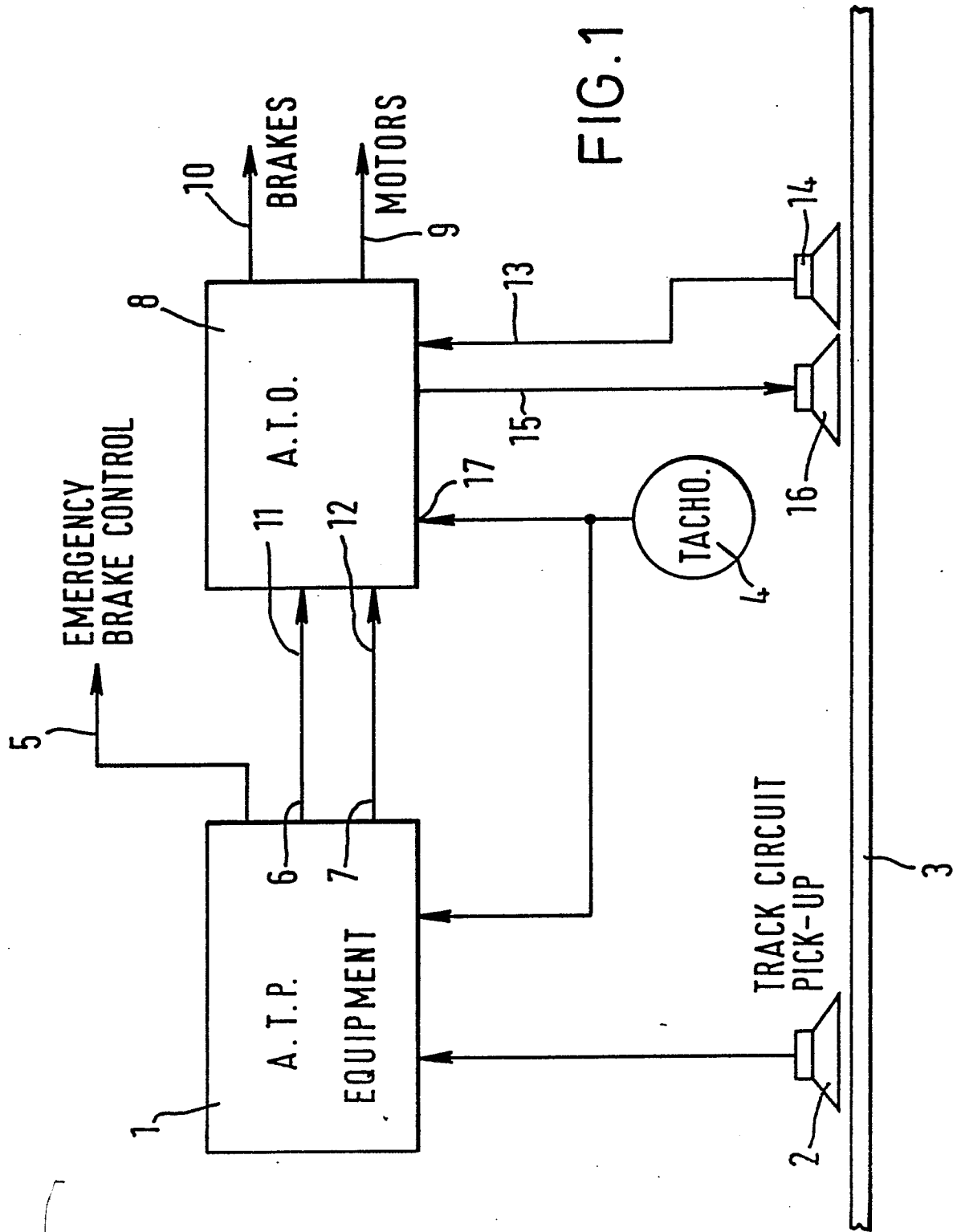
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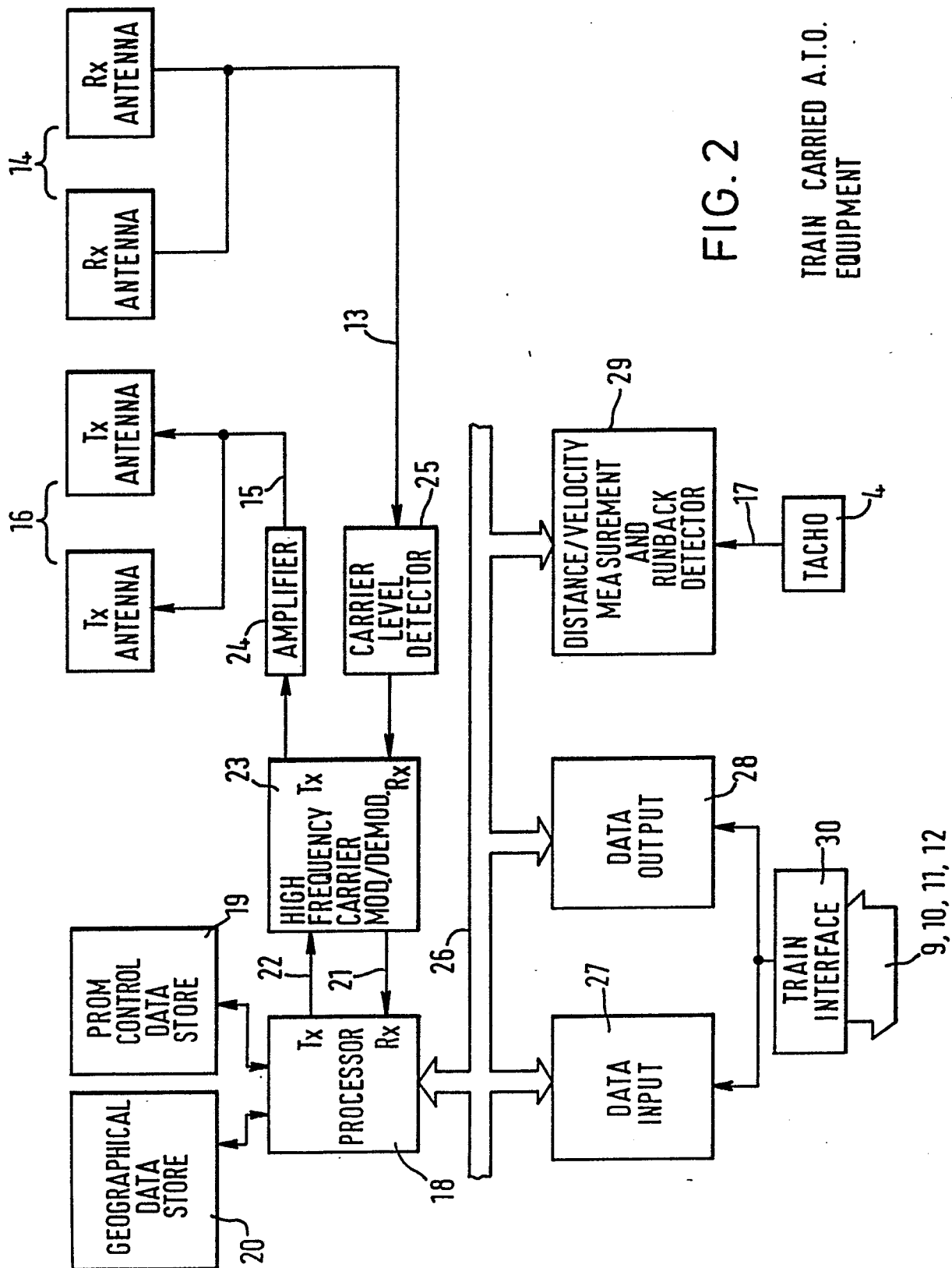
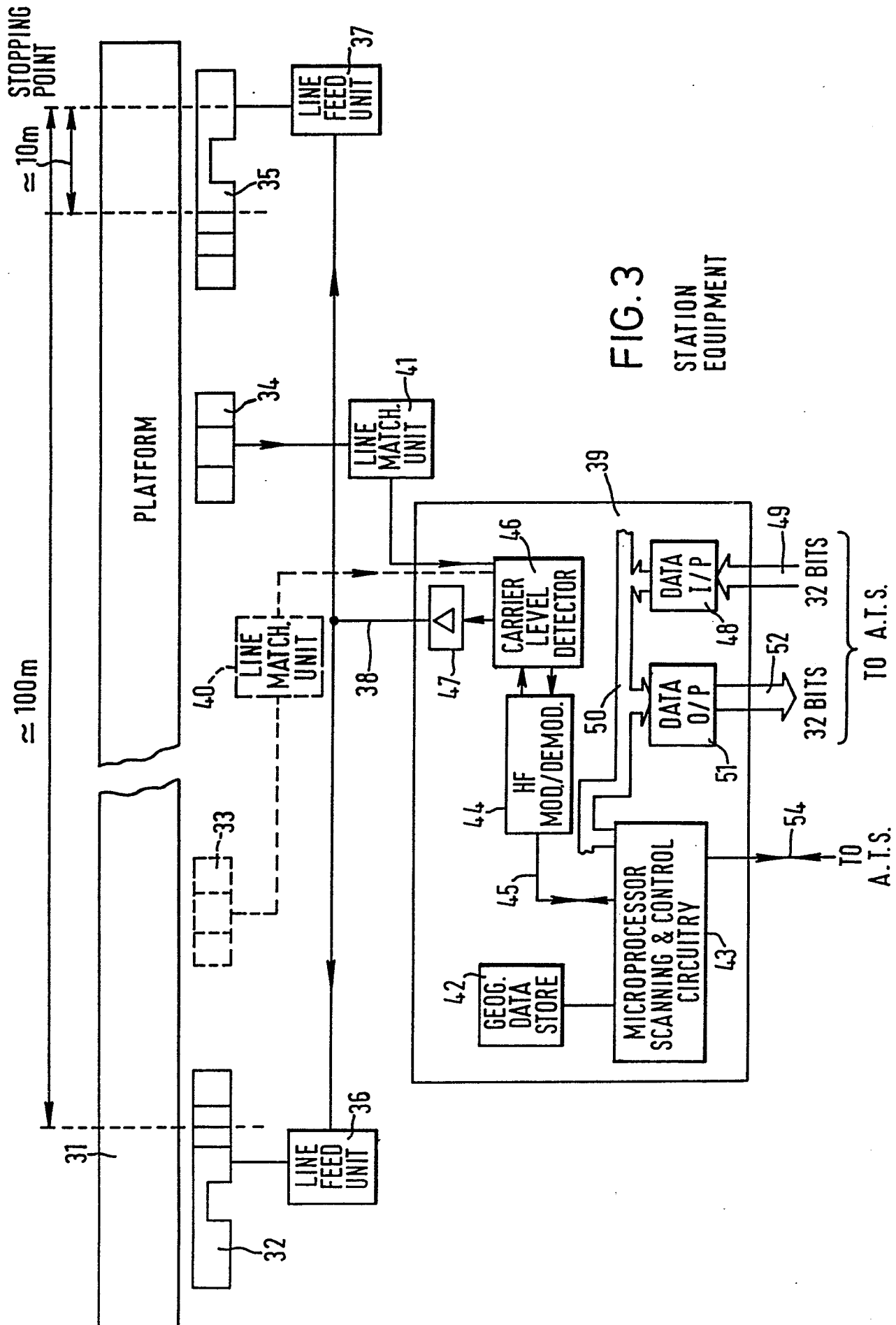


FIG. 2

TRAIN CARRIED A.T.O.
EQUIPMENT



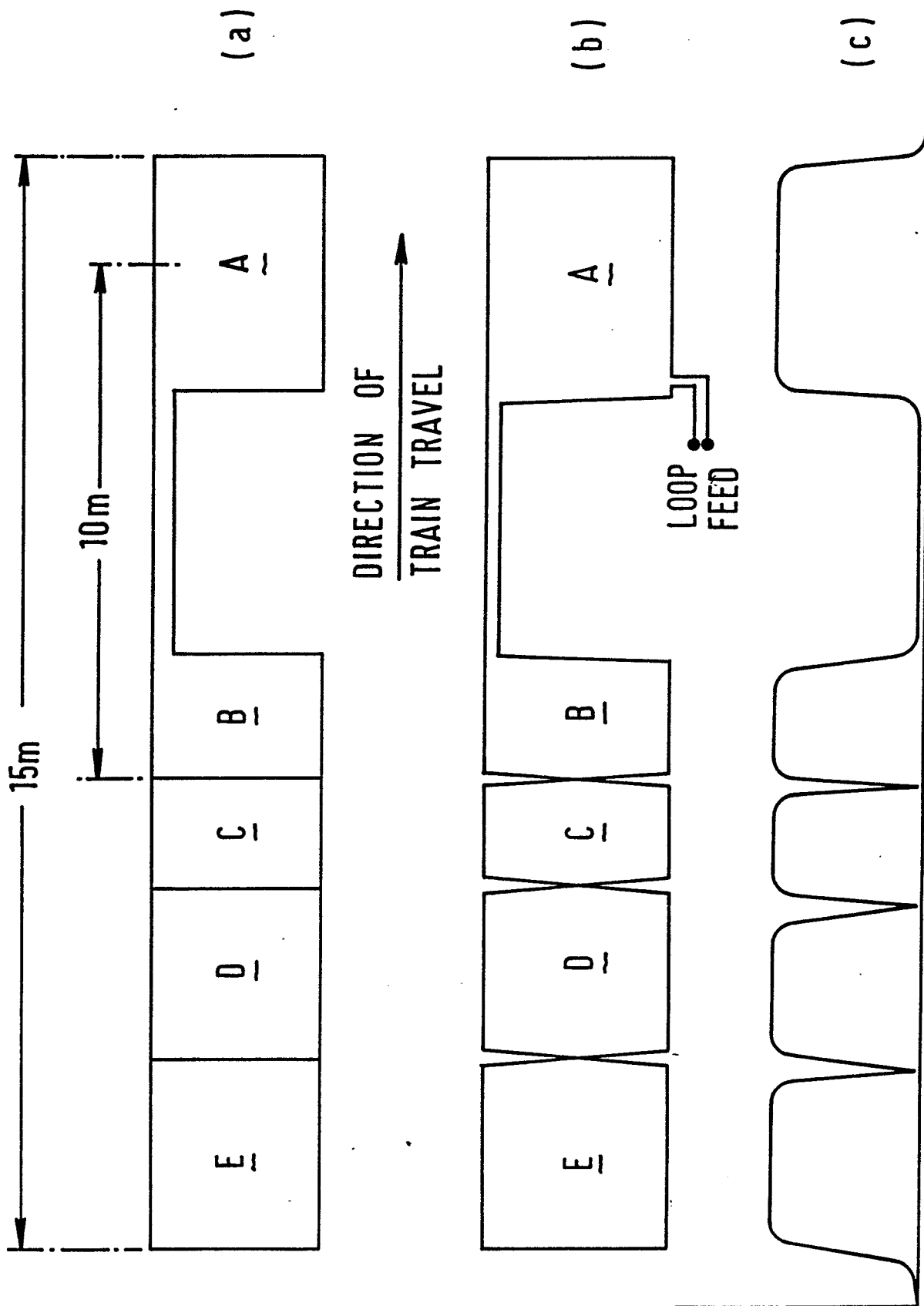


FIG. 4

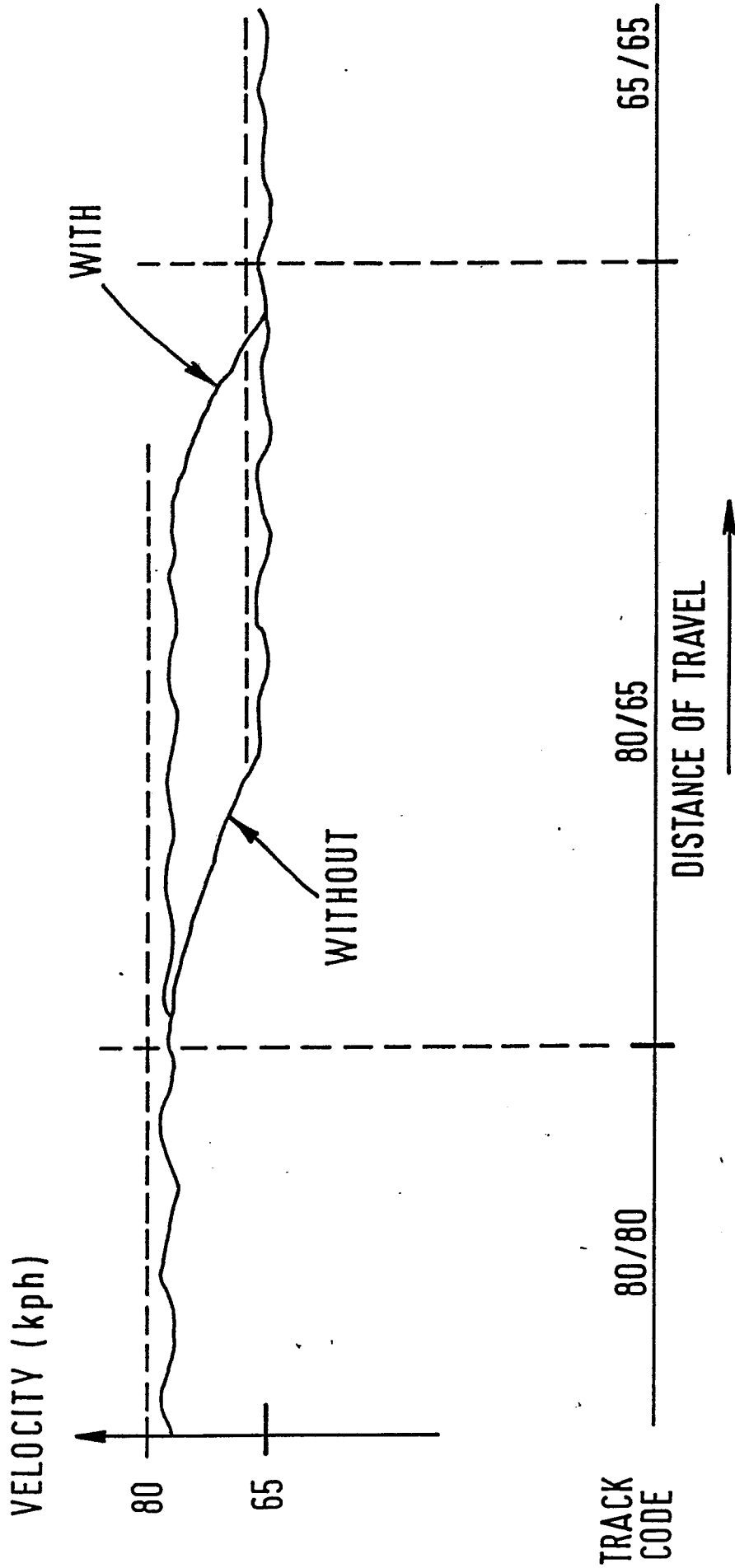


FIG. 5