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NOTICE OF ENTITLEMENT

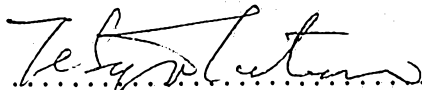
I, Tetsuya KATADA, care of Kabushiki Kaisha Komatsu Seisakusho, 3-6, Akasaka 2-chome, Minato-ku, Tokyo 107 Japan , being authorised by the Applicant/Nominated Person in respect of Application No 35404/89 state the following:-

The Applicant/Nominated Person has, for the following reasons, gained entitlement from the actual inventor(s):-

The Applicant/Nominated Person is the assignee of the actual inventor(s).

The Applicant/Nominated Person for the grant of the patent is the applicant of the application listed in the declaration under Article 8 of the PCT.

DATED this 17th day of October 1991


Tetsuya Katada

DECLARATION IN SUPPORT OF AN
APPLICATION FOR PATENT

In support of the Application made

Full name(s)
of Applicant(s)

by Kabushiki Kaisha Komatsu Seisakusho

for a patent for an invention entitled:

Title of
Invention

Apparatus for controlling movement of vehicle

I/~~we~~ Tetsuya KATADA, PresidentFull name(s) and
address(es) of Declarant(s)of Kabushiki Kaisha Komatsu Seisakusho, 3-6, Akasaka 2-chome,
Minato-ku, Tokyo 107 Japan

do solemnly and sincerely declare as follows:

1. ~~I am/We are the applicant(s) for the patent.~~

(or, in the case of an application by a body corporate)

1. I am/~~we~~ are authorised by

Kabushiki Kaisha Komatsu Seisakusho

the applicant(s) for the patent to make this declaration
on its/~~their~~ behalf.2. ~~I am/We are the actual inventor(s) of the invention.~~

(or, where a person other than the inventor is the applicant)

2. Toyochi ONO

Full name(s) and
address(es) of
Inventor(s)

of 688-5, Tokunobu, Hiratsuka-shi, Kanagawa-ken 254 Japan

(respectively)

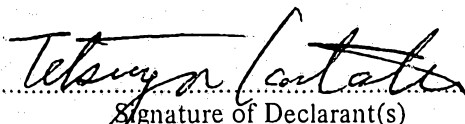
is/~~are~~ the actual inventor(s) of the invention and the facts
upon which the applicant(s) is/~~are~~ entitled to make the
application are as follows:Set out how Applicant(s)
derive title from actual
inventor(s) e.g. The
Applicant(s) is/are the
assignee(s) of the
invention from the
inventor(s)assignment which took place on April 14, 1990 whereby the
actual inventor assigned the invention to the said applicant.

Declared at Tokyo, Japan

this 27th

day of December

1990

Signature of Declarant(s)
Tetsuya KATADA, President of Kabushiki
Kaisha Komatsu Seisakusho

(12) PATENT ABRIDGMENT (11) Document No. AU-B-35404/89
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 622182

- (54) Title
APPARATUS FOR CONTROLLING MOVEMENT OF VEHICLE
- (51)⁴ International Patent Classification(s)
G05D 001/02
- (21) Application No. : **35404/89** (22) Application Date : **01.05.89**
- (87) PCT Publication Number : **WO90/13856**
- (43) Publication Date : **29.11.90**
- (44) Publication Date of Accepted Application : **02.04.92**
- (71) Applicant(s)
KABUSHIKI KAISHA KOMATSU SEISAKUSHO
- (72) Inventor(s)
TOYOICHI ONO
- (74) Attorney or Agent
SPRUSON & FERGUSON , GPO Box 3898, SYDNEY NSW 2001
- (56) Prior Art Documents
AU 12442/88 G05D 1/02
- (57) Claim

1. An apparatus for controlling the movement of a vehicle, wherein said apparatus includes electric wave transmitting means for transmitting a first electric wave, a second electric wave and a third electric wave in synchronization with each other from predetermined positions on the ground different from each other and an unit mounted on the vehicle comprises:

a first antenna and a second antenna arranged on the vehicle in parallel with each other with a predetermined distance kept therebetween,

first time difference detecting means for detecting the difference between the time when said first electric wave reaches said first antenna and the time when said second electric wave reaches said first antenna as well as the difference between the time when said first electric wave reaches said first antenna and said third electric wave reaches said first antenna,

position detecting means for detecting the position where the vehicle is presently located, based on said time differences detected by said first time difference detecting means,

second time difference detecting means for detecting the

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(10) 622182

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difference between the time when said first electric wave reaches said first antenna and the time when said first electric wave reaches said second antenna,

attitude angle detecting means for detecting the attitude angle with which the vehicle is moving, based on said time difference detected by said second time difference detecting means,

storing means for allowing target courses for the vehicle to be stored therein,

calculating means for calculating a steering angle command for allowing the vehicle to move along one of said target courses, based on the position where the vehicle is presently located, the attitude angle with which the vehicle is moving and the target courses, and

steering control means for controlling a steering angle to be assumed by the vehicle to a certain magnitude in conformity with said steering angle command.



(51) 国許許付類
G05D 17/02

(11) 国際公開番号

WO 90/13856

A1

(43) 國際公開日

1990年11月15日 (15. 11. 1990)

(21) 国际出願番号 PCT/JP89/00459

(22) 國際出願日 1989年5月1日 (01. 05. 89)

(71) 出願人（米国を除くすべての指定国について）

株式会社 小松製作所

(KABUSHIKI KAISHA KOMATSU SEISAKUSHO)[JP/JP]

〒107 東京都港区赤坂2丁目3番6号 Tokyo, (JP)

(72) 発明者 ; および

(75) 発明者／出願人（米国についてのみ）

小野豊一 (ONO, Toyochichi) [JP/JP]

〒254 神奈川県平塚市徳延688-5 Kanagawa, (JP)

(74) 代理人

井理士 木村隆久 (KIMURA, Takahisa)

〒104 東京都中央区銀座2丁目11番2号 銀座大作ビル6階
Tokyo, (JP)

(81) 指定国

AT (歐洲特許), AU, BE (歐洲特許), CH (歐洲特許),

+ DE (歐洲特許), FR (歐洲特許), GB (歐洲特許),

IT (歐洲特許), LU (歐洲特許), NL (歐洲特許),

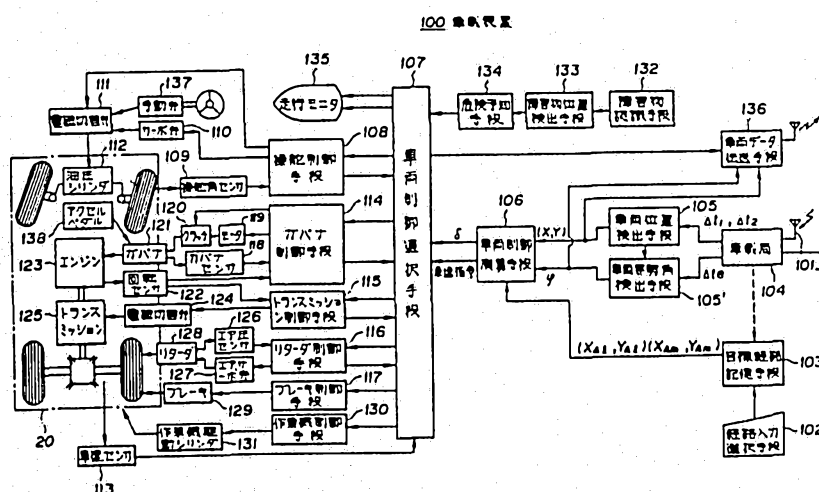
SE (歐洲特許), U.S.

添付公開書類

國際調查報告書

(54) Title: Apparatus for controlling movement of vehicle

(54) 発明の名称 車両の走行制御装置



- 100- APPARATUS MOUNTED ON A VEHICLE
102- PATH INPUT SELECTING MEANS
103- TARGET PATH MEMORIZING MEANS
104- STATION MOUNTED ON A VEHICLE
105- VEHICLE POSITION DETECTING MEANS
105- VEHICLE ATTITUDE ANGLE DETECTING MEANS
106- VEHICLE CONTROL ARITHMETIC MEANS
a.- VEHICLE SPEED COMMAND
107- VEHICLE CONTROL SELECTING MEANS
108- STEERING CONTROL MEANS
109- STEERING ANGLE SENSOR
110- SERVO VALVE
111- ELECTROMAGNETIC CHANGE-OVER VALVE
112- HYDRAULIC CYLINDER
113- VEHICLE SPEED SENSOR
114- GOVERNOR CONTROL MEANS
115- TRANSMISSION CONTROL MEANS
116- RETARDER CONTROL MEANS
117- BRAKE CONTROL MEANS
118- GOVERNOR SENSOR
119- MOTOR
120- CLUTCH
121- GOVERNOR
122- ROTATION SENSOR
123- ENGINE
124- ELECTROMAGNETIC CHANGE-OVER VALVE
125- TRANSMISSION
126- AIR PRESSURE SENSOR
127- AIR SERVO VALVE
128- RETARDER
129- BRAKE
130- WORKING MACHINE CONTROL MEANS
131- WORKING MACHINE DRIVING CYLINDER
132- OBSTACLE IDENTIFYING MEANS
133- OBSTACLE POSITION DETECTING MEANS
134- DANGER PREDICTING MEANS
135- TRAVEL MONITOR
136- VEHICLE DATA TRANSFER MEANS
137- MANUAL VALVE
138- ACCELERATING PEDAL

(57) Abstract

A travelling control apparatus used for the guided travelling of a vehicle, such as a dump truck. According to this apparatus, first, second and third synchronized radio waves (m1), (m2), (m3) are transmitted from different predetermined positions on the ground. These radio waves (m1), (m2), (m3) are received by a vehicle (20), and the position and attitude angle of the vehicle are detected on the basis of differences in the time of reception between the radio waves. A steering command for moving the vehicle along a preset travelling path is determined on the basis of the preset travelling path and the position and attitude angle of the vehicle, and a vehicle steering angle is controlled to a level which is in conformity with this steering command.

出願日が1990年10月3日より前の国際出願におけるDEの指定は、先のドイツ民主共和国の領域を除く、ドイツ連邦共和国の領域において有効である。

ABSTRACT

An apparatus for controlling the movement of a vehicle such as a dump truck or the like so as to allow the movement of the vehicle to be correctly induced is disclosed.

5 With the apparatus constructed according to the present invention, a first electric wave (m_1), a second electric wave (m_2) and a third electric wave (m_3) are transmitted in synchronization with each other from predetermined locations on the ground different from each other.

10 Then, the electric wave (m_1), the electric wave (m_2) and the electric wave (m_3) are received by two antennas mounted on the vehicle (20), whereby the position where the vehicle (20) is presently located and the attitude angle assumed by the vehicle (20) are detected based on the
15 difference between the time the electric wave (m_1) reaches the vehicle (20) and the time when the electric wave (m_2) reaches the vehicle (20) as well as the difference between the time when the electric wave (m_1) reaches the vehicle (20) and the time when the electric wave (m_3) reaches the
20 vehicle (20).



SPECIFICATION

APPARATUS FOR CONTROLLING MOVEMENT OF VEHICLE

5

TECHNICAL FIELD

The present invention relates to an apparatus for controlling the movement of a working vehicle such as a dump truck or the like wherein the apparatus is intended to assist the vehicle to properly perform a given operation and moreover allow the vehicle to move in an unmanned manner, i.e., without necessity for any driver to be ^{in control of} ~~ridden on~~ the vehicle.

15

BACKGROUND ART

With respect to an apparatus for allowing a vehicle to move along a preset target course while the movement of the vehicle is automatically induced, it is essential that the apparatus exactly detects the position where the vehicle is presently located, and performances of the apparatus are practically determined depending on how exactly the present position of the vehicle is detected.

A conventional apparatus of the foregoing type which assures that the target course can be changed to another one, i.e., a conventional apparatus of the foregoing type



having excellent flexibility in respect of a target course to be assumed by the vehicle is typically disclosed in an official gazette of, e.g., Japanese Laid-Open Patent NO. 70618/1986 which is titled "System for allowing a vehicle to
5 move in an unmanned manner". According to the system of the prior invention, as the vehicle moves, a distance of movement of the vehicle on a two-dimensional coordinate is sequentially calculated with reference to the speed of movement of the vehicle and the orientation angle of
10 movement of the vehicle so that the present position of the vehicle on the two-dimensional coordinate is detected based on the sequentially calculated values.

With the conventional apparatus as described above, the speed of movement of the vehicle is detected by a vehicle
15 speed sensor and the orientation angle of movement of the vehicle is detected by a gyro-compass serving as an orientation sensor. For the reason, it is unavoidable that detection errors derived from these sensors are increased accumulatively. Especially, an error of the running speed
20 appearing due to slippage of tires during movement of the vehicle and an error of the orientation angle appearing due to offset drift of the gyro-compass remarkably degrade the detection accuracy in respect of the position of the vehicle to be detected.

25 Therefore, the conventional apparatus has a drawback



that induction control is generally accomplished with a deteriorated accuracy.

To obviate the foregoing drawback, a proposal has been made such that a station having suitable marks and induction
5 cables laid thereon is installed at a known important location on the target course and a sensor is mounted on the vehicle to detect the magnetic field generated by the marks and the induction cables, whereby the detection error derived from the speed sensor and other components is
10 periodically corrected based on outputs from the sensor. According to the aforementioned proposal having exterior induction units such as marks or the like employed therefor, however, the conventional apparatus has still a drawback that it fails to secure certain flexibility in respect of
15 variation of the target course to another one to be assumed by the vehicle, because the target course is unchangeably determined.

The present invention has been made with the foregoing background in mind.

20 Therefore, an object of the present invention is to provide an apparatus for controlling the movement of a vehicle wherein the apparatus assures that the movement of the vehicle can exactly be induced while an advantage of flexibility in respect of a target course to be assumed by
25 the vehicle is sustained.



DISCLOSURE OF THE INVENTION

According to one aspect of the present invention there is disclosed an apparatus for controlling the movement of a vehicle, wherein said apparatus includes electric wave transmitting means for transmitting a
5 first electric wave, a second electric wave and a third electric wave in synchronization with each other from predetermined positions on the ground different from each other and an unit mounted on the vehicle comprises:

a first antenna and a second antenna arranged on the vehicle in
10 parallel with each other with a predetermined distance kept therebetween,

first time difference detecting means for detecting the difference between the time when said first electric wave reaches said first antenna and the time when said second electric wave reaches said first antenna as well as the difference between the time when said first electric wave
15 reaches said first antenna and said third electric wave reaches said first antenna,

position detecting means for detecting the position where the vehicle is presently located, based on said time differences detected by said first time difference detecting means,

20 second time difference detecting means for detecting the difference between the time when said first electric wave reaches said first antenna and the time when said first electric wave reaches said second antenna,

attitude angle detecting means for detecting the attitude angle with which the vehicle is moving, based on said time difference detected

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by said second time difference detecting means,

storing means for allowing target courses for the vehicle to be stored therein,

calculating means for calculating a steering angle command for the
5 allowing the vehicle to move along one of said target courses, based on position where the vehicle is presently located, the attitude angle with which the vehicle is moving and the target courses, and

steering control means for controlling a steering angle to be assumed by the vehicle to a certain magnitude in conformity with said
10 steering angle command.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram which schematically illustrates by way of example the structure of an unit installed on the ground in accordance with the present invention,

15 Fig. 2 is a block diagram which schematically illustrates an unit mounted on a vehicle in accordance with the present invention,

Fig. 3 is a schematic view which illustrates by way of example two running courses which are preset in working sites,

Fig. 4 is a diagram in the form of a table which illustrates by way
20 of example the content of items stored in target course storing means,

Fig. 5 is an illustrative view which shows a principle for detecting the position where the vehicle is presently located,

Fig 6 is

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an illustrative view which shows a principle for detecting the attitude angle of the vehicle, Fig. 7 is a perspective view which illustrates the operative state of the vehicle of which position is deviated from a predetermined one and of which attitude angle is deviated from a predetermined one, and Fig. 8(a) and Fig. 8(b) are a schematic view which illustrates by way of example the content of items displayed on the screen of a running monitor, respectively.

BEST MODE FOR CARRYING OUT THE INVENTION

Now, the present invention will be described in detail hereinafter with reference to the accompanying drawings which illustrates a preferred embodiment of the present invention.

An apparatus for controlling the movement of a vehicle in accordance with the present invention comprises an unit installed on the ground as shown in Fig. 1 and an unit mounted on the vehicle as shown in Fig. 2.

The unit installed on the ground includes a main station 11 which has a function of transmitting an electric wave m_1 . In addition, the unit 10 includes substations 12 and 13 which have a function of transmitting electric waves m_2 and m_3 in synchronization with the electric wave m_1 .

Specifically, on receipt of the electric wave m_1 transmitted from the main station 11, the substations 12 and



13 extract a synchronizing signal therefrom and then transmit the electric waves m_2 and m_3 in synchronization with the synchronizing signal.

It should be noted that the phase of the electric wave m_1 is deviated from the phase of the electric wave m_2 by a quantity of time which is determined by dividing the distance between the main station 11 and the substation 12 (constant value) with a transmission speed of the electric wave, while the phase of the electric wave m_1 is deviated from the phase of the electric wave m_3 by a quantity of time which is determined by dividing the distance between the main station 11 and the substation 13 (constant value) with the speed of the electric wave.

The main station 11 and the substations 12 and 13 are installed at predetermined positions in a working site as shown in Fig. 3 in order to detect the position where a working vehicle 20 such as a dump truck or the like is presently located and the attitude angle assumed by the vehicle 20.

First, description will be made below with respect to a principle for detection the position where the vehicle 20 is presently located.

As shown in Fig. 5, a two-dimensional coordinate system is established for the working site such that the coordinates (known) of the main station 11 and the



substations 12 and 13 are represented by $(0, 0)$, (a_1, b_1) and (a_2, b_2) , the coordinate of the vehicle 20 is represented by (X, Y) , the distance between the main station 11 and the vehicle 20 is represented by L_1 , the distance
 5 between the substation 12 and the vehicle 20 is represented by L_2 and the distance between the substation 13 and the vehicle 20 is represented by L_3 . Thus, the difference ΔL_1 between the distance L_1 and the distance L_2 and the difference ΔL_2 between the distance L_1 and the distance L_3
 10 can be expressed based on the foregoing assumption in accordance with the following equation (1).

$$\begin{aligned} \Delta L_1 &= \sqrt{X^2 + Y^2} \\ &\quad - \sqrt{(X - a_1)^2 + (Y - b_1)^2} \\ \Delta L_2 &= \sqrt{X^2 + Y^2} \\ &\quad - \sqrt{(X - a_2)^2 + (Y - b_2)^2} \\ &\quad \dots (1) \end{aligned}$$

When the position (X, Y) of the vehicle 20 where the distance difference ΔL_1 assumes a constant value is sequentially plotted, the result is that, e.g., a curved line b identified by a solid line in Fig. 5 is scribed.

In other words, the distance difference ΔL_1 assumes a certain constant value ΔL_{1-b} , no matter how far the position of the vehicle 20 on the curved line b varies.

25 Similarly, other curved lines a and c to f are scribed



by sequentially plotting the position (X, Y) of the vehicle 20 where the distance difference ΔL_2 assumes a constant value in the same manner as mentioned above, respectively.

On the other hand, curved lines g to o identified by 5 dotted lines in Fig. 5 are scribed by sequentially plotting the position (X, Y) of the vehicle 20 where the distance difference ΔL_2 assumes a constant value, respectively. Thus, the distance difference ΔL_2 assumes a certain constant value of, e.g., ΔL_{2-i} , no matter how far the 10 position of the vehicle 20 varies on the curved line i.

The distance difference ΔL_1 corresponds to the difference Δt_1 between the time when the electric wave m_1 transmitted from the main station 11 reaches the vehicle 20 and the time when the electric wave m_2 transmitted from the 15 substation 12 reaches the vehicle 20.

Similarly, the distance difference ΔL_2 corresponds to the difference Δt_2 between the time when the electric wave m_1 transmitted from the main station 11 reaches the vehicle 20 and the time when the electric wave m_3 transmitted from 20 the substation 13 reaches the vehicle 20.

Therefore, the present position (X, Y) of the vehicle 20 in the two-dimensional coordinate system can be measured and determined based on the relationship between the distance differences ΔL_1 and ΔL_2 expressed by the equation 25 (1) by obtaining the distance differences ΔL_1 and ΔL_2 with



reference to the time differences Δt_1 and Δt_2 .

As shown in Fig. 7, the vehicle 20 is equipped with antennas 101a and 101b on the front and rear sides thereof. Since the antennas 101a and 101b are arranged in that way,
5 determination of the time differences Δt_1 and Δt_2 can be accomplished, based on the electric wave received by either one of the antennas 101a and 101b, by measuring the difference between the time when the electric wave m_1 is received and the time when the electric wave m_2 is received
10 as well as the difference between the time when the electric wave m_1 is received and the time when the electric wave m_3 is received.

In this case, it is assumed that the position of the antenna which has been practically used for the purpose of
15 receiving the electric wave coincides with the position (X, Y) of the vehicle 20.

Next, description will be made below with respect to a principle for obtaining the attitude angle of the vehicle
20.

As shown in Fig. 6, the angle defined by the line segment extending between the main station 11 and the substation 12 and the line segment extending between the main station 11 and the rear antenna 101b is represented by θ , the angle defined by the line segment extending between
25 the antennas 101a and 101b and the line segment extending



from the rear antenna 101b while intersecting the line segment extending between the main station 11 and the front antenna 101b at a right angle is represented by α , the angle defined by the line segment between the main station 11 and the front antenna 101a and the line segment extending between the main station 11 and the rear antenna 101b is represented by β , the distance between the main station 11 and the front antenna 101a is represented by l_1 , the distance between the main station 11 and the rear antenna 101b is represented by l_2 , the distance between the front antenna 101a and the rear antenna 101b is represented by a (known value), and the attitude angle of the vehicle 20 relative to a X-coordinate is represented by ψ . Then, the relationship expressed by the following equations (2) to (7) is established among the foregoing parameters.

$$\theta = \tan^{-1} (Y / X) \quad \dots (2)$$

$$\Delta l \doteq l_1 - l_2 \quad \dots (3)$$

$$a \cdot \sin \alpha = \Delta l \quad \dots (4)$$

$$l_2 = \sqrt{X^2 + Y^2} \quad \dots (5)$$

$$l_2 \cdot \sin \beta = a \cdot \cos \alpha \quad \dots (6)$$

$$\psi = \pi / 2 - \theta - \alpha + \beta \quad \dots (7)$$

The distance difference Δl represented by the equation (3) can be expressed below in a modified state by using the difference Δt_e between the time when the electric wave



transmitted from the main station 11 reaches the front antenna 101a and the time when the electric wave transmitted from the main station 11 reaches the rear antenna 101b.

$$\Delta l = c \cdot \Delta t_e \quad \dots (8)$$

where c designates the speed with which the electric wave has been transmitted to the front antenna 101a and the rear antenna 101b.

The angle θ can be obtained in accordance with the equation (2), when the coordinate (X, Y) of the vehicle can be measured and determined in accordance with the aforementioned principle for measuring the respective positions.

In addition, the angle α can be obtained based on the distance difference Δl in accordance with the equation (4), when the distance difference Δl is determined by measuring the time difference Δt_e shown in the equation (8), and the angle β can be obtained based on the distance l_2 and the angle α in accordance with the equation (6), when the distance l_2 is derived from the coordinate (X, Y) in accordance with the equation (5).

Once the angles θ , α and β are determined, the attitude angle ψ of the vehicle 20 can be obtained in accordance with the equation (7).

Referring to Fig. 6, it is assumed that the position



where the rear antenna 101b is arranged on the vehicle 20 coincides with the position (X, Y) of the vehicle 20.

Although the time difference Δt_e represented by the equation (8) is determined by using the electric wave transmitted from the main station 11, it is possible to detect the attitude angle ψ by using the electric wave transmitted from the substation 12 or 13 in place of the electric wave transmitted from the main station 11.

As shown in Fig. 3, two target courses A and B are preset in order to assure that the vehicle 20 moves to the working site while the movement of the vehicle 20 is correctly induced.

Referring to Fig. 4, respective coordinates (X_{A1}, Y_{A1}) to (X_{An}, Y_{An}) in the two-dimensional coordinate system for a plurality of positions A_1 to A_n on the target course A, respective coordinates (X_{B1}, Y_{B1}) to (X_{Bn}, Y_{Bn}) in the two-dimensional coordinate system for a plurality of positions B_1 to B_n on the target course B, a series of vehicle speed commands at the positions A_1 to A_n as well as at the positions B_1 to B_n and a series of work commands for allowing the vehicle 20 to work at a specific position among the foregoing positions are shown in the drawing in the form of a table.

The content of items shown on the table in Fig. 4 is preliminarily stored in target course storing means 103 by

actuating course input selecting means 102 (e.g., a key board) in the unit 100 mounted on the vehicle 20 as shown in Fig. 2. In addition, designation for the target courses A and B shown in Fig. 2 is accomplished by actuating the
5 course input selecting means 102.

Now, it is supposed that, e.g., the target course A is designated by actuating the course input selecting means 102. In this case, the following control is carried out in order to assure that the movement of the vehicle 20 along
10 the target course A is correctly induced.

Specifically, for example, a station 104 mounted on the vehicle 20 shown in Fig. 2 determines the difference Δt_1 between the time when the electric wave m_1 reaches the rear antenna 101b and the time when the electric wave m_2 reaches
15 the rear antenna 101b and the difference Δt_2 between the time when the electric wave m_1 reaches the rear antenna 101b and the time when the electric wave m_3 reaches the rear antenna 101b.

It should be noted that the station 104 mounted on the
20 vehicle 20 includes detecting means for detecting the phase difference between the phase of the electric wave m_1 and the phase of the electric wave m_2 and the phase difference between the phase of the electric wave m_1 and the phase of the electric wave m_3 so that the time difference Δt_1 and
25 the time difference Δt_2 are determined based on the



foregoing phase differences.

As mentioned above, the time difference Δt_1 and the time difference Δt_2 correspond to the distance difference ΔL_1 and the distance difference ΔL_2 represented by the equation (1). Thus, vehicle position detecting means 105 determines the position (X, Y) of the vehicle 20, i.e., the position (X, Y) of the rear antenna 101b based on the time differences Δt_1 and Δt_2 in accordance with the equation (1).

On the other hand, in response to the electric wave transmitted from a specific station among the main station 11 and the substations 12 and 13, e.g, the main station 10, the station 104 mounted on the vehicle 20 determines the difference between the time when the electric wave reaches the front antenna 101a and the time when the electric wave reaches the rear antenna 101b, i.e, the time difference Δt_e between the foregoing times represented by the equation (8) between the electric wave so as to allow a signal corresponding to the time difference Δt_e to be outputted to vehicle attitude angle detecting signal 105'.

It should be noted that the time difference Δt_e is detected based on the difference between the phase of the electric wave transmitted from the main station 11 and received by the front antenna 101a and the phase of the electric wave transmitted from the main station 11 and



received by the rear antenna 101b.

The vehicle attitude angle detecting means 105' determines the attitude angle ψ of the vehicle 20 based on the time difference Δt_e in accordance with the equations
5 (2), (4) and (7).

In such a manner as mentioned above, the vehicle position detecting means 105 and the vehicle attitude angle detecting means 105' determine the present position (X, Y) of the vehicle 20 and the attitude angle ψ at an interval of
10 time τ , respectively, so that signals representing the present position (X, Y) and the attitude angle ψ assumed by the vehicle 20 are added to vehicle control calculating means 106.

In response to the inputted foregoing signals, the
15 vehicle control calculating means 106 sequentially reads from the target course storing means 103 a series of vehicle speed commands with respect to the positions A_1 to A_n on the target course A as well as the coordinates (X_{A1}, Y_{A1}) to (X_{An}, Y_{An}) indicating the positions A_1 to A_n shown in Fig.
20 4. Subsequently, the vehicle control calculating means 106 calculates a steering command based on the coordinates representing the positions A_1 to A_n , the present position (X, Y) where the vehicle 20 is presently located and the attitude angle ψ of the vehicle 20.

25 Here, a step of calculating the steering command will



be described below with reference to Fig. 7.

It is considered that the target course A is composed of a plurality of bent lines, each extending between the adjacent coordinates, i.e., two coordinates selected from a series of the coordinates $(Y_{A1}, Y_{A1}), (X_{A2}, X_{A2}), \dots (X_{An}, Y_{An})$. Then, it is assumed that the movement course of the vehicle 20 is successively shifted one after another in accordance with the order as represented by $\overline{A_1A_2} \rightarrow \overline{A_2A_3} \rightarrow \dots \overline{A_{n-1}A_n}$. It should be added that determination of the foregoing shifting is made based on the present position (X, Y) of the vehicle 20 which has been detected by the vehicle position detecting means 105.

Now, it is supposed that the vehicle 20 assumes a line segment $\overline{A_lA_m}$ and it is presently located at the position (X, Y). At this time, the lateral deviation ε of the vehicle 20 from the line segment $\overline{A_lA_m}$ is expressed by the following equation (9).

$$\varepsilon = \frac{(X_{Am} - Y_{A_l}) \cdot X_K - (X_{Am} - X_{A_l}) \cdot X_K}{\sqrt{(Y_{Am} - Y_{A_l})^2 + (X_{Am} - X_{A_l})^2}} + \frac{(X_{Am} - X_{A_l}) \cdot Y_{A_l}}{\sqrt{(Y_{Am} - Y_{A_l})^2 + (X_{Am} - X_{A_l})^2}} \dots (9)$$

In addition, the deviation angle $\Delta\psi$ of the vehicle 20

relative to the line segment $\overline{A_l A_m}$ is expressed by the following equation (10) in the form of a difference between the angular inclination of the line segment $\overline{A_l A_m}$ and the attitude angle ψ shown in Fig. 6.

$$\Delta \phi = \tan^{-1} \frac{Y_{Am} - Y_A \ell}{X_{Am} - X_A \ell} - \phi \quad \dots (10)$$

The steering angle command δ required for allowing the movement of the vehicle 20 along the running course A to be correctly induced is determined in accordance with the following equation (11) based on the lateral displacement ϵ and the deviation angle $\Delta\psi$ of the vehicle 20.

$$\delta = K_1 \cdot \varepsilon + K_2 \cdot \Delta \phi \quad \dots (11)$$

15 where K_1 and K_2 are a constant, respectively.

Thus, the steering angle command δ can be determined when the lateral deviation ε and the deviation angle $\Delta\psi$ of the vehicle 20 are obtained.

The vehicle control calculating means 106 shown in Fig. 2 obtains the steering angle command δ of the vehicle 20 in the above-described manner so that the signal representing the steering angle command δ as well as the signals representing the vehicle speed commands in correspondence to the coordinates (X_{A1}, Y_{A1}) and (X_{Am}, Y_{Am}) read from the target course storing means 103 are added to steering



control means 108 via vehicle control selecting means 107.

The steering control means 108 obtains the deviation of the signal representing the steering angle command δ from the output signal outputted from a steering angle sensor 109
5 for indicating the actual steering angle of the vehicle 20 so that a flow rate of pressurized hydraulic oil flowing through a servo-valve 110 is controlled correctly.

The pressurized hydraulic oil which has been controlled by the servo-valve 110 is fed to a hydraulic cylinder 112
10 via an electromagnetic switching valve 111, whereby the hydraulic cylinder 112 is actuated such that the actual steering angle coincides with the angle which has been set in response to the steering angle command δ .

Consequently, the vehicle 20 is steered in such a
15 direction that the lateral deviation ξ and the deviation angle ϕ are eliminated. This leads to the result that the vehicle 20 runs along the course A.

On the other hand, the vehicle control selecting means 107 is operated in conformity with the aforementioned
20 vehicle commands and the actual vehicle speed detected by a vehicle speed sensor 113 in such a manner that the signal representing a governor position command is added to governor controlling means 114, the signal representing a speed stage command is added to transmission controlling
25 means 115, the signal representing a retarder brake pressure



command is added to retarder controlling means 116 and the signal representing a brake command is added to brake controlling means 117.

5 The governor controlling means 114 determines the deviation of the signal representing the governor position command from the output signal outputted from a governor sensor 118 to represent the actual governor position so that a motor 119 for driving a governor 121 is driven depending on the foregoing deviation.

10 As a result, the position of a fuel control lever in the governor 121 operatively connected to the motor 119 via a clutch 120 is adjusted to the position which has been determined in conformity with the foregoing governor position command.

15 In response to the signal representing the speed stage command, the transmission controlling means 115 actuates an electromagnetic switching valve 124 when the actual engine speed of an engine 123 detected by an engine speed sensor 122 reaches the engine speed adapted to the command speed stage, whereby the speed stage of a transmission 125 is set
20 to the command speed stage.

The retarder controlling means 116 obtains the deviation of the signal representing the retarder brake pressure command from the output signal outputted from an
25 air pressure sensor 126 to represent the actual retarder



brake pressure, whereby a flow rate of pressurized hydraulic oil flowing through an air servo-valve 127 is correctly controlled depending on the foregoing deviation. This causes a retarder 128 to be driven thereby to determine a
5 braking force in conformity with the foregoing command.

In response to the signal representing the brake command, the brake controlling means 117 drives a brake 129 and stops the vehicle 20.

As the respective components 114 to 117 as mentioned
10 above function correctly, the vehicle 20 runs at the speed corresponding to the vehicle speed command.

As shown in Fig. 4, a working command w at the position (X_{A2}, Y_{A2}) on the target course A is stored in the target course storing means 103 shown in Fig. 2.

15 In the case where the working command w is stored in that way, the vehicle control selecting means 107 shown in Fig. 2 receives the working command w via the vehicle control calculating means 106 so that the signal representing the work command w is added to working machine
20 controlling means 130.

As a result, the working machine controlling means 130 drives a working machine driving cylinder 131 at the position (X_{A2}, Y_{A2}) on the target course A so that the working machine (a vessel in the case of a dump truck)
25 conducts a work in conformity with the working command.



It should be noted that obstacle recognizing means 132 (e.g., a TV camera) photographs the direction of movement of the vehicle 20 so that the signal derived from the foregoing photographing is added to obstacle position detecting means 133.

In a case where an obstacle appears on the screen of the obstacle recognizing means 132, the obstacle position detecting means 133 performs a conventional image processing operation to detect the position of the obstacle so that the signal representing the position of the obstacle is added to danger predicting means 134.

When the position of the obstacle is located in the direction of movement of the vehicle 20, the danger predicting means 134 is operated such that the signal representing a danger is added to the vehicle control selecting means 107. This causes the vehicle control selecting means 107 to output a steering control signal to the steering control means 108 so as to allow the vehicle 20 to move around the obstacle. Otherwise, the vehicle control selecting means 107 outputs a vehicle stop signal to the brake controlling means 117.

Additionally, the vehicle control selecting means 107 executes the following function. Specifically, in response to signals from the target course storing means 103, the vehicle position detecting means 105, the steering angle



sensor 109, the engine speed sensor 122 and the vehicle speed sensor 113, the vehicle control selecting means 107 allows the present position of the vehicle 20 on the target course A to be displayed on the screen of a running monitor 5 135, e.g., as shown in Fig. 8(a). In addition, the actual steering angle, the actual engine speed and the actual vehicle speed are displayed at suitable locations on the screen of the running monitor 135.

It should be added that a certain location in the 10 vicinity of the position where the vehicle 20 is presently located may be displayed on the screen of the running monitor 135 in an enlarged scale, as shown in Fig. 8(b).

On the other hand, the signals representing the target course A, the position where the vehicle 20 is presently 15 located, the actual steering angle, the actual engine speed and the actual vehicle speed are added to vehicle data transferring means 136 from the vehicle control selecting means 107.

The vehicle data transferring means 136 transmits to 20 vehicle data receiving means 14 of the unit 10 installed on the ground shown in Fig. 1 the foregoing signals and the signal representing a vehicle number given to the vehicle 20 via an electric wave.

The vehicle data receiving means 14 serves to allow the 25 respective received signals to be added to the vehicle



monitor 15 and vehicle controlling means 16. This causes the vehicle monitor 15 to display the position where the vehicle 20 is presently located on the target course A, the actual steering angle, the actual engine speed and the actual vehicle speed on the screen thereof. In addition, in response to signals transmitted from other vehicle, the vehicle monitor 15 displays similar data to the foregoing ones on the screen thereof with respect to the other vehicle.

10 In response to the aforementioned signals, the vehicle controlling means 16 practically recognizes the current status on the movement of the vehicle 20. Additionally, in response to the signals transmitted from the other vehicle, the vehicle controlling means 16 practically recognizes the current status on the movement of the other vehicle.

The content of various items displayed on the screen of the vehicle monitor and the current status on the movement of the vehicles practically recognized by the vehicle controlling means 16 are utilized for properly controlling each of the vehicles.

It should be noted that a manual valve 137 shown in Fig. 2 is actuated when a manual steering operation is performed. An acceleration pedal 138 is operatively linked to the fuel control lever of the governor 121.

25 It should be added that the target course storing unit



17 shown in Fig. 1 is arranged in order to transfer an information on the running courses and other informations shown by way of example in Fig. 4 to the vehicle 20 from the ground side.

5 Specifically, the information on the running courses and other informations stored in the target course storing unit 17 are transmitted to the main station 11 via an electric wave. At this time, the station 104 mounted on the vehicle 20 shown in Fig. 2 receives the information on the
10 running courses and other informations and they are then stored in the target course storing means 103.

 With such construction as mentioned above, there is no need of allowing the information on the running courses and other informations to be inputted into the course input
15 selecting means 102.

 The present invention has been described above with respect to the embodiment wherein two antennas 101a and 101b are mounted on the vehicle 20 at the front part and the rear part of the same to detect the attitude angle of the vehicle
20 20. However, the present invention should not be limited only to this embodiment. Alternatively, the antennas 101a and 101b may be mounted, e.g., on the both sides of the vehicle 20, i.e., on the left-hand and right-hand sides of the same. In other words, the antennas 101a and 101b can be
25 mounted at arbitrarily determined positions on the vehicle



20, provided that an adequate distance is maintained therebetween (It should be noted that it is not allowable that they are mounted in the spaced relationship in the vertical direction).

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INDUSTRIAL APPLICABILITY

As will be apparent from the above description, the apparatus for properly controlling the movement of a vehicle in accordance with the present invention is usefully
10 available for the purpose of allowing the movement of the vehicle along a predetermined course to be correctly induced with a high accuracy. Especially, the apparatus of the present invention is preferably employable in a case where a vehicle for outdoor works such as a dump truck or the like
15 vehicle is operated under an unmanned condition, i.e., without necessity for any driver to be ^{in control of} ~~ridden on~~ the vehicle.

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The claims defining the invention are as follows:

1. An apparatus for controlling the movement of a vehicle,
wherein said apparatus includes electric wave transmitting means for
transmitting a first electric wave, a second electric wave and a third
5 electric wave in synchronization with each other from predetermined
positions on the ground different from each other and an unit mounted on
the vehicle comprises:

a first antenna and a second antenna arranged on the vehicle
in parallel with each other with a predetermined distance kept
10 therebetween,

first time difference detecting means for detecting the
difference between the time when said first electric wave reaches said
first antenna and the time when said second electric wave reaches said
first antenna as well as the difference between the time when said first
15 electric wave reaches said first antenna and said third electric wave
reaches said first antenna,

position detecting means for detecting the position where the
vehicle is presently located, based on said time differences detected by
said first time difference detecting means,

20 second time difference detecting means for detecting the
difference between the time when said first electric wave reaches said
first antenna and the time when said first electric wave reaches said
second antenna,

attitude angle detecting means for detecting the attitude
25 angle with which the vehicle is moving, based on said time difference
detected by said second time difference detecting means,

storing means for allowing target courses for the vehicle to
be stored therein,

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calculating means for calculating a steering angle command for allowing the vehicle to move along one of said target courses, based on the position where the vehicle is presently located, the attitude angle with which the vehicle is moving and the target courses, and

5 steering control means for controlling a steering angle to be assumed by the vehicle to a certain magnitude in conformity with said steering angle command.

2. An apparatus for controlling the movement of a vehicle as claimed in claim 1, wherein one of the first antenna and the second
10 antenna is arranged on the front part of the vehicle and the other one is arranged on the rear part of

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the vehicle.

3. An apparatus for controlling the movement of a vehicle as claimed in claim 1, wherein said first time difference detecting means detects the difference between the time when
5 the first electric wave reaches the first antenna and the time when the second electric wave reaches the first antenna, based on the difference between the phase of the first electric wave received by the first antenna and the phase of the second electric wave received by the first
10 antenna and moreover detects the difference between the time when the first electric wave reaches the first antenna and the time when the third electric wave reaches the first antenna, based on the difference between the phase of the first electric wave received by the first antenna and the
15 phase of the third electric wave received by the first antenna.

4. An apparatus for controlling the movement of a vehicle as claimed in claim 1, wherein said second time difference detecting means detects the difference between the time when
20 the first electric wave reaches the first antenna and the time when the first electric wave reaches the second antenna, based on the difference between the phase of the first electric wave received by the first antenna and the phase of the electric wave received by the second antenna.

25 5. An apparatus for controlling the movement of a vehicle



as claimed in claim 1, wherein said storing means serves to allow coordinates representing a plurality of locations on each of the target courses to be stored therein as a target course to be assumed by the vehicle.

5 6. An apparatus for controlling the movement of a vehicle as claimed in claim 1, wherein said storing means stores in addition to the target courses a vehicle speed command indicating a speed to be assumed by the vehicle on each of the target courses, and wherein the unit mounted on the vehicle includes means for adjusting the speed of the
10 vehicle to a speed conforming to said vehicle speed command.

7. An apparatus for controlling the movement of a vehicle as claimed in claim 1, wherein said storing means stores in addition to the target courses a work command indicating a work to be conducted by the vehicle on one of the target courses, wherein the unit mounted on the
15 vehicle includes means for allowing the vehicle to conduct a work conforming to said work command.

8. An apparatus for controlling the movement of a vehicle, said apparatus being substantially as described with reference to the accompanying drawings.

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DATED this EIGHTH day of JANUARY 1992

K K Komatsu Seisakusho

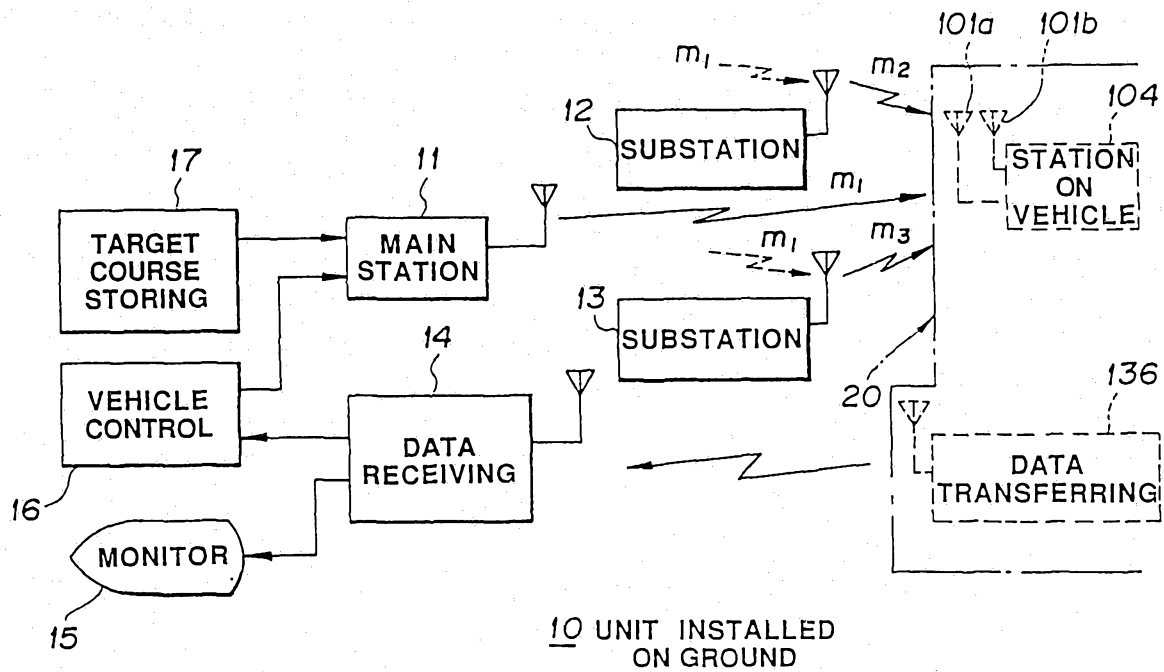
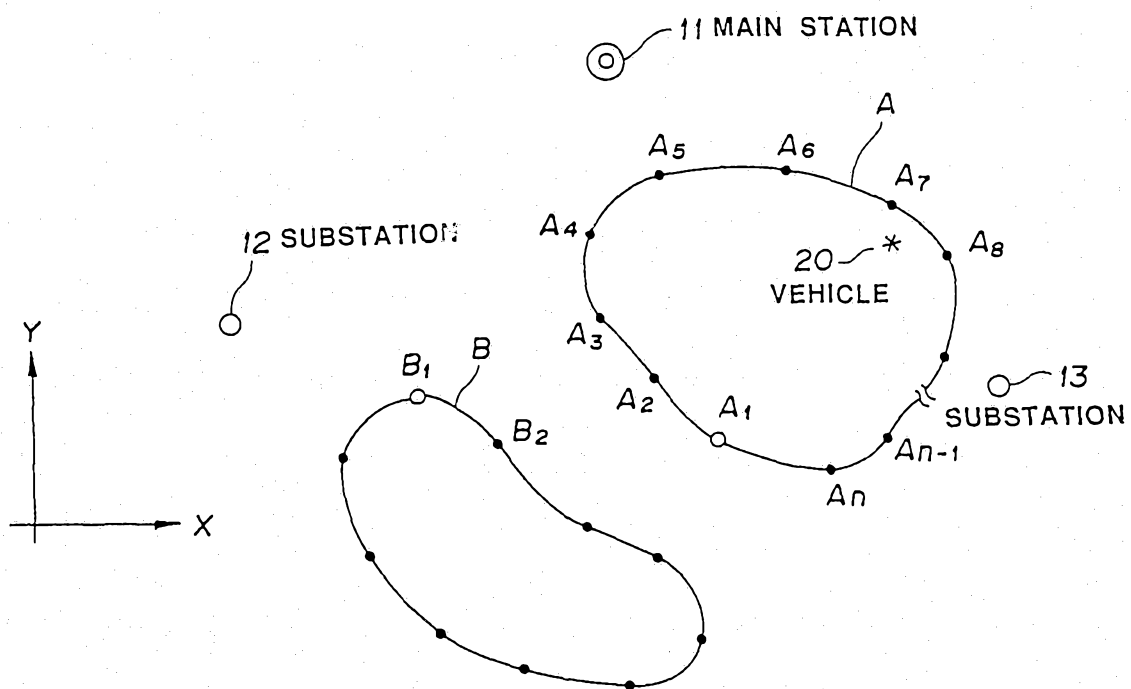
25

Patent Attorneys for the Applicant

SPRUSON & FERGUSON

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**FIG. 1****FIG. 3**

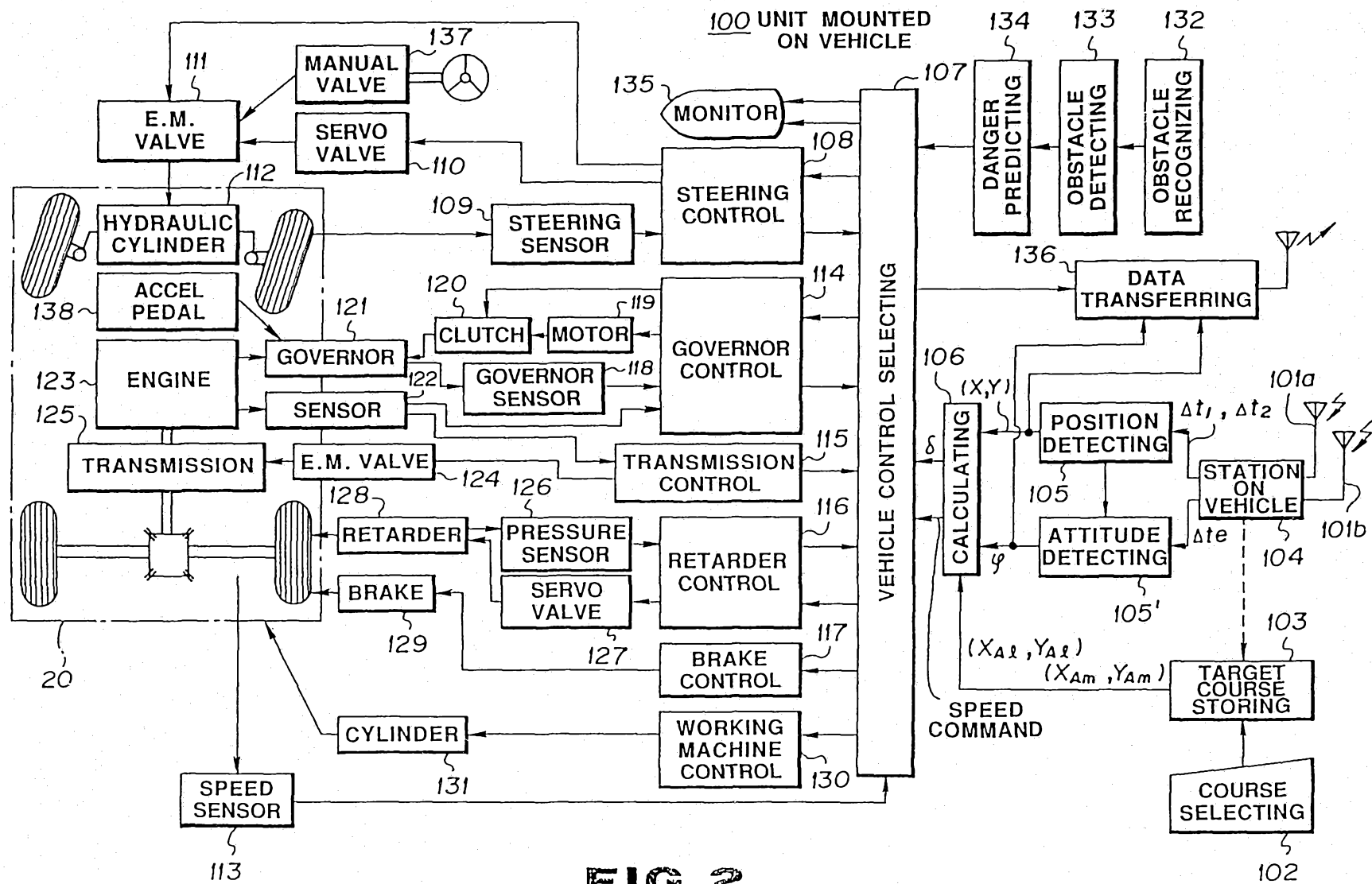


FIG. 2

TARGET COURSE ID CODE		X-COORDINATE	Y-COORDINATE	SPEED COMMAND	WORKING COMMAND	
COURSE POSITION NO.						
A	1	X_{A1}	Y_{A1}	0		---
	2	X_{A2}	Y_{A2}	20	W	---
	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	---
	n	X_{An}	Y_{An}	10		---
B	1	X_{B1}	Y_{B1}	0	W	---
	2	X_{B2}	Y_{B2}	15		---
	$\vdots$	$\vdots$	$\vdots$	$\vdots$		---

FIG. 4

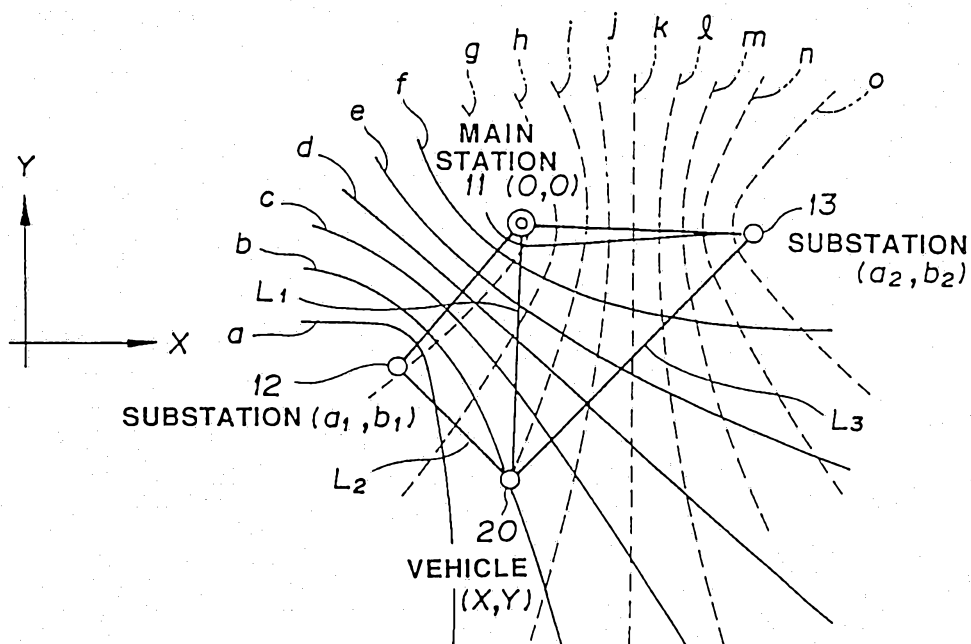
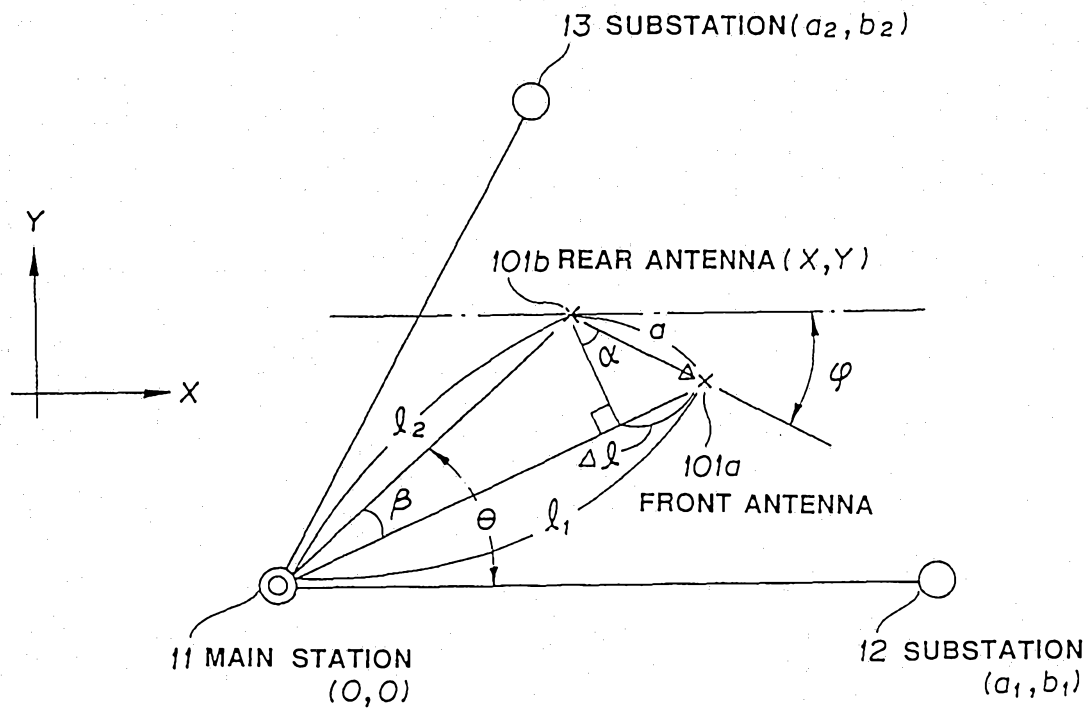
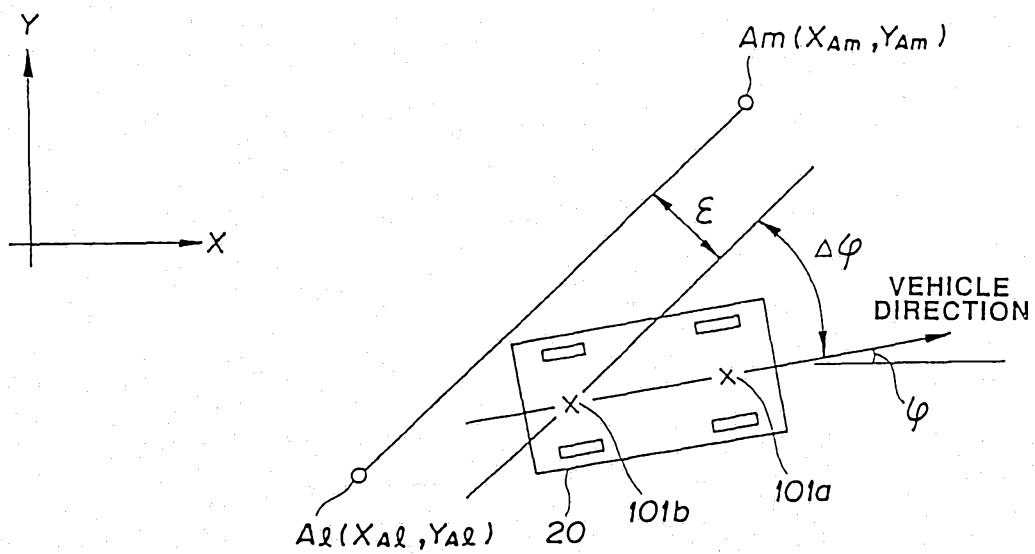
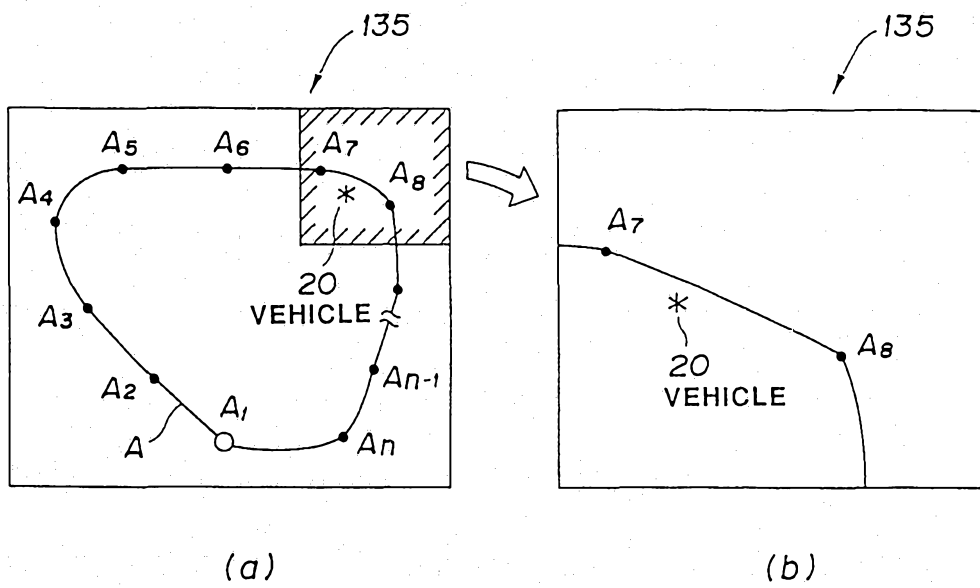


FIG. 5

**FIG. 6****FIG. 7**

**FIG. 8**

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP89/00459

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both International Classification and IPC		
Int. Cl ⁴	G05D1/02	
II. FIELDS SEARCHED		
Minimum Documentation Searched		
Classification System	Classification Symbols	
IPC	G05D1/02	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
Jitsuyo Shinan Koho	1970 - 1989	
Kokai Jitsuyo Shinan Koho	1971 - 1989	
III. DOCUMENTS CONSIDERED TO BE RELEVANT *		
Category *	Citation of Document, " with indication, where appropriate, of the relevant passages "	Relevant to Claim No. "
Y	JP, A, 60-233710 (Shinko Electric Co., Ltd.) 20 November 1985 (20. 11. 85) Page 2, upper part, right column, line 17 to lower part, left column, line 4 (Family: none)	1-6
Y	JP, A, 54-117705 (Kubota, Ltd.) 12 September 1979 (12. 09. 79) Page 2, lower part, left column, lines 13 to 16 (Family: none)	1-6
Y	JP, A, 57-39701 (Yanmar Agricultural Equipment Co., Ltd.) 5 March 1982 (05. 03. 82) Page 4, upper part, right column, lines 13 to 20 (Family: none)	1-7
* Special categories of cited documents. ¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
May 19, 1989 (19. 05. 89)	June 5, 1989 (05. 06. 89)	
International Searching Authority	Signature of Authorized Officer	
Japanese Patent Office		

国 際 調 査 報 告

国際出願番号 PCT/JP 89/ 00459

I. 発明の属する分野の分類		
国際特許分類 (IPC) Int. Cl. G 0 5 D 1 / 0 2		
II. 国際調査を行った分野		
調 査 を 行 っ た 最 小 限 資 料		
分 類 体 系	分 類 記 号	
IPC	G 0 5 D 1 / 0 2	
最小限資料以外の資料で調査を行ったもの		
日本国実用新案公報 1970-1989年 日本国公開実用新案公報 1971-1989年		
III. 関連する技術に関する文献		
引用文献の カテゴリー ※	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	請求の範囲の番号
Y	JP, A, 60-233710 (神鋼電機株式会社) 20. 11月. 1985 (20. 11. 85) 第2頁, 上段右欄第17-下段左欄第4行 (ファミリーなし)	1-6
Y	JP, A, 54-117705 (久保田鉄工株式会社) 12. 9月. 1979 (12. 09. 79) 第2頁, 下段左欄第13-第16行 (ファミリーなし)	1-6
Y	JP, A, 57-39701 (ヤンマー農機株式会社) 5. 3月. 1982 (05. 03. 82) 第4頁, 上段右欄第13-第20行 (ファミリーなし)	1-7
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IV. 認 証		
国際調査を完了した日 19. 05. 89	国際調査報告の発送日 05.06.89	
国際調査機関 日本国特許庁 (ISA/JP)	権限のある職員 特許庁審査官 池 田 敏 行	5 H 7 3 0 4