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(54) RASTER-BASED CONTOUR SWATHING FOR GUIDANCE AND VARIABLE-RATE CHEMICAL APPLICATION

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(58) **Field of Classification Search**
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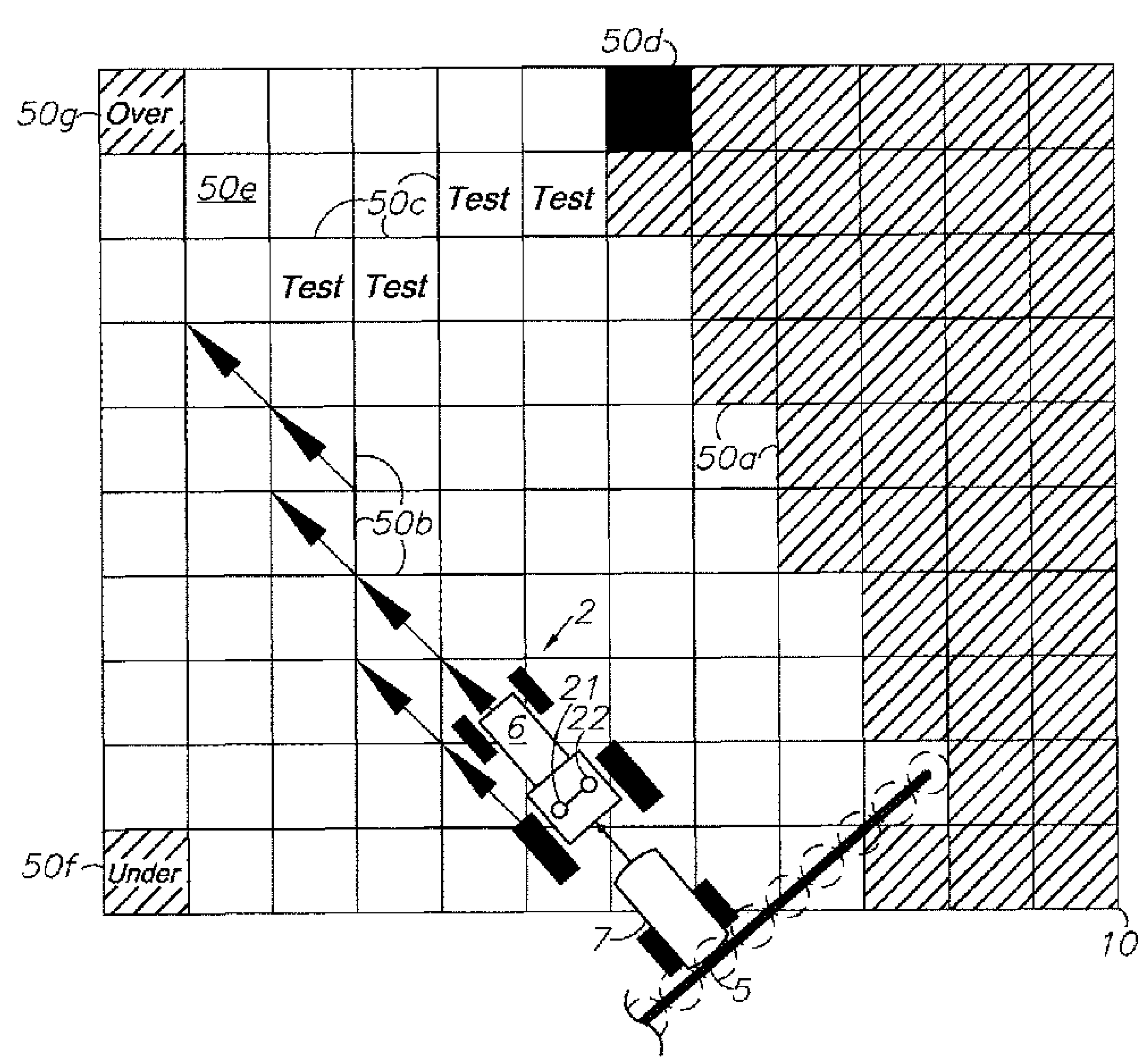
(57) **ABSTRACT**

A raster-based system for global navigation satellite system (GNSS) guidance includes a vehicle-mounted GNSS antenna and receiver. A processor provides guidance and/or autosteering commands based on GNSS-defined pixels forming a grid representing an area to be treated, such as a field. Specific guidance and chemical application methods are provided based on the pixel-defined treatment areas and preprogrammed chemical application prescription maps, which can include variable chemical application rates and dynamic control of the individual nozzles of a sprayer.

6 Claims, 9 Drawing Sheets



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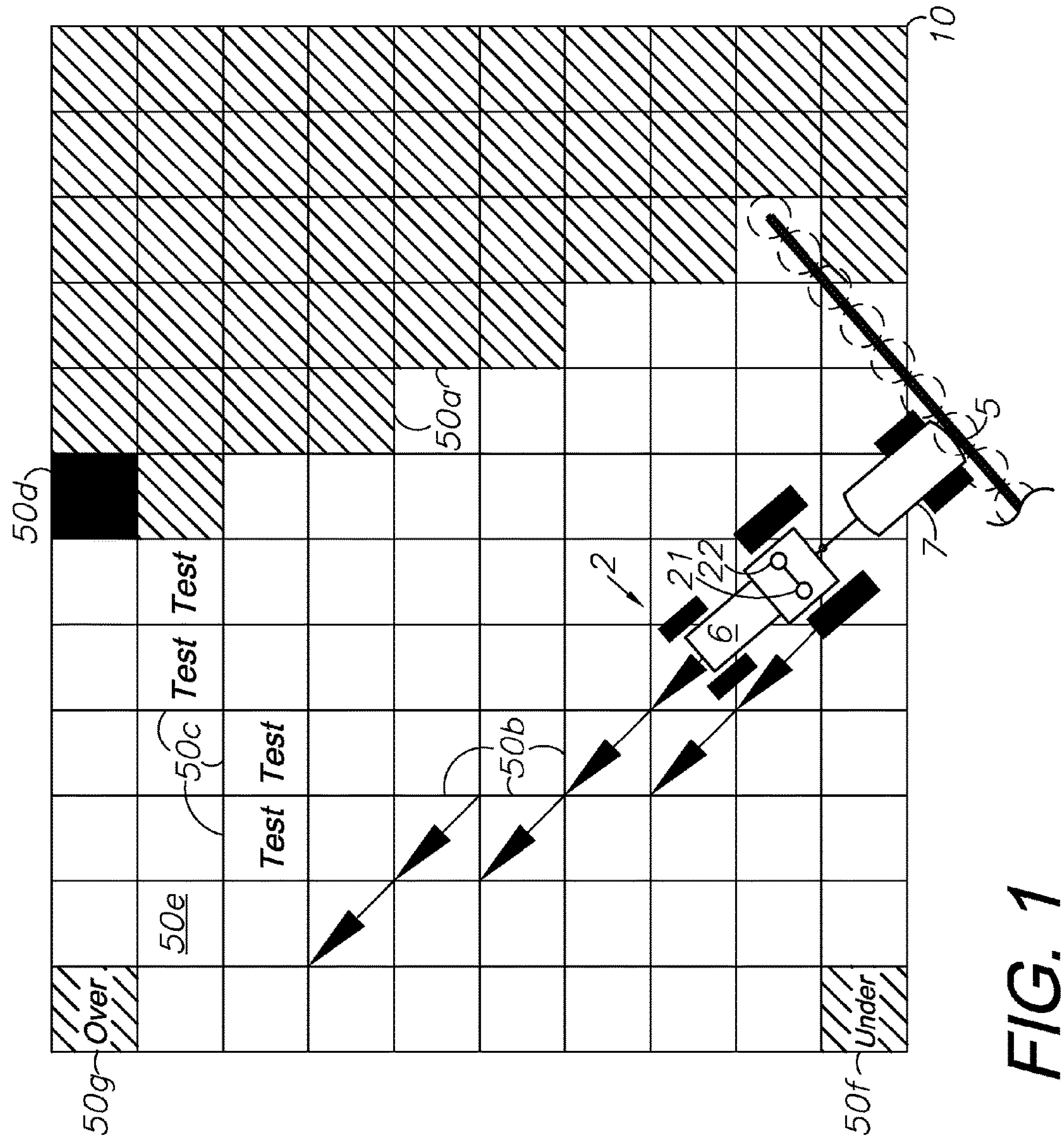
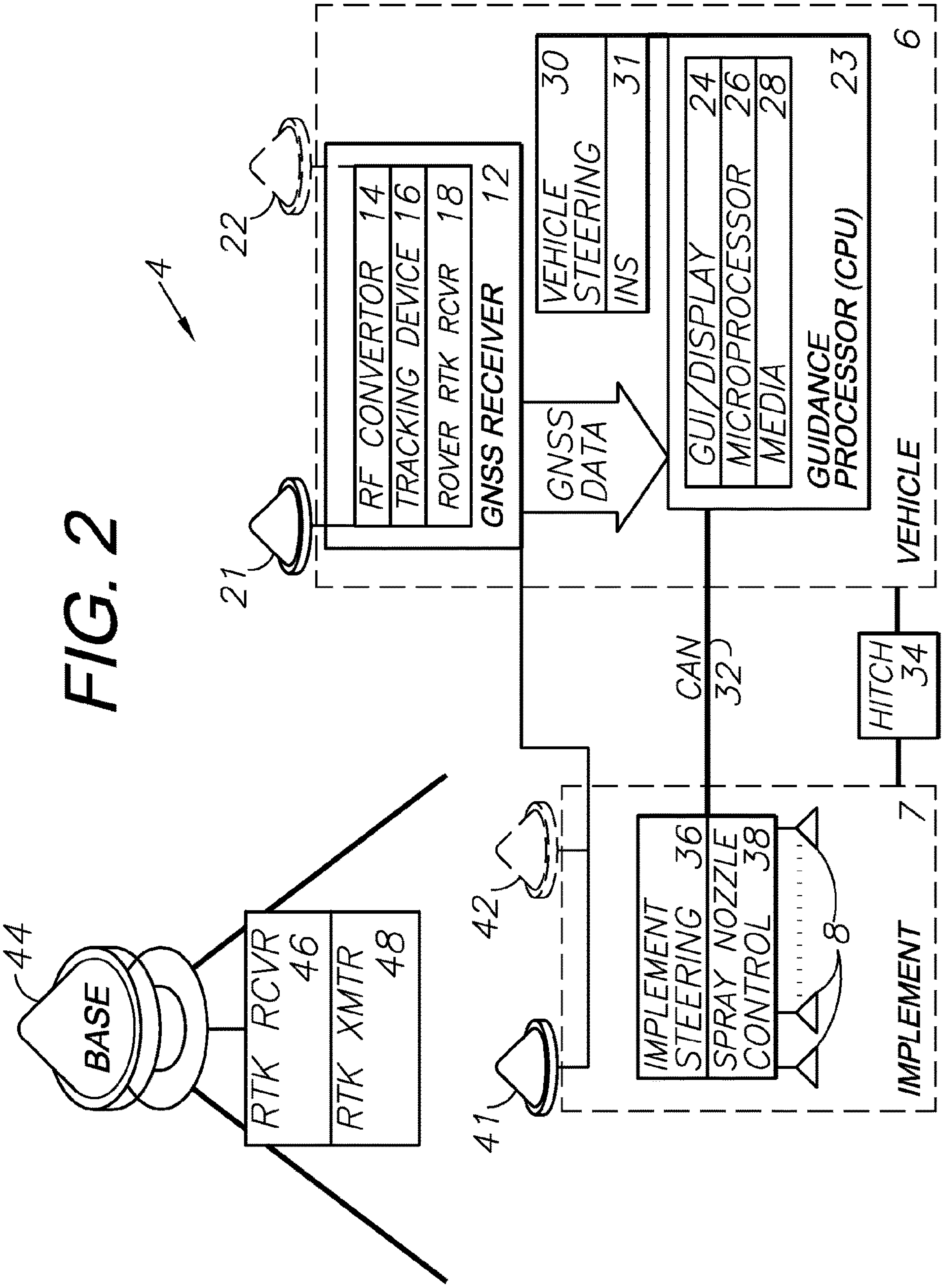
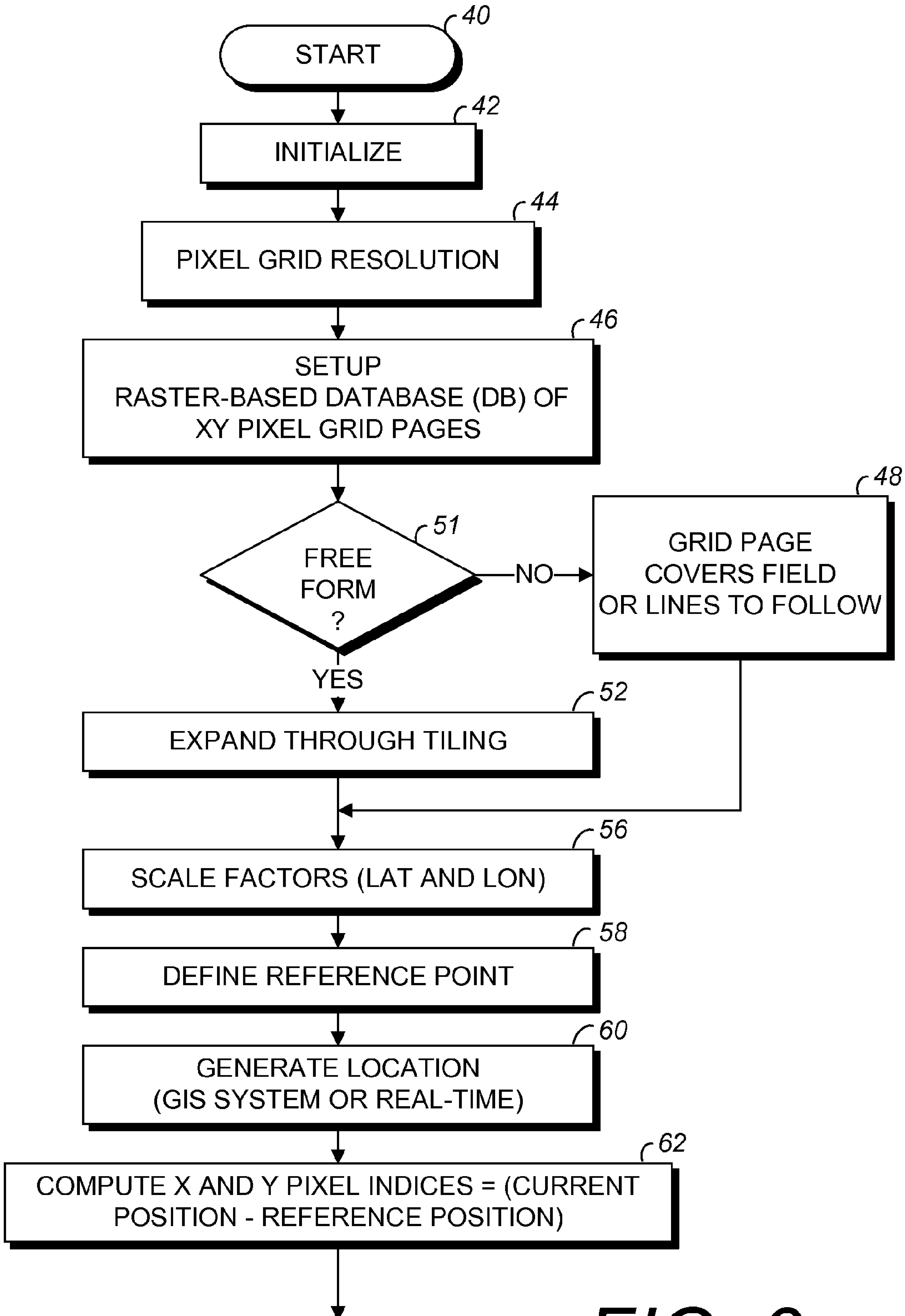

10
50a
50b
50c
50d
50e
50f
50g
Test
Test
Test
Test
Over
Under
2
5
6
7
21
22

FIG. 1

FIG. 2


4
21
22
RF CONVERTOR 14
TRACKING DEVICE 16
ROVER RTK RCVR 18
GNSS RECEIVER 12
GNSS DATA
VEHICLE STEERING 30
INS 31
GUI/DISPLAY 24
MICROPROCESSOR 26
MEDIA 28
GUIDANCE PROCESSOR (CPU) 23
6
VEHICLE
CAN 32
HITCH 34
41
42
IMPLEMENT STEERING 36
SPRAY NOZZLE CONTROL 38
8
7
IMPLEMENT
44
BASE
RTK RCVR 46
RTK XMTR 48



CONTINUED ON FIG. 3b

FIG. 3a

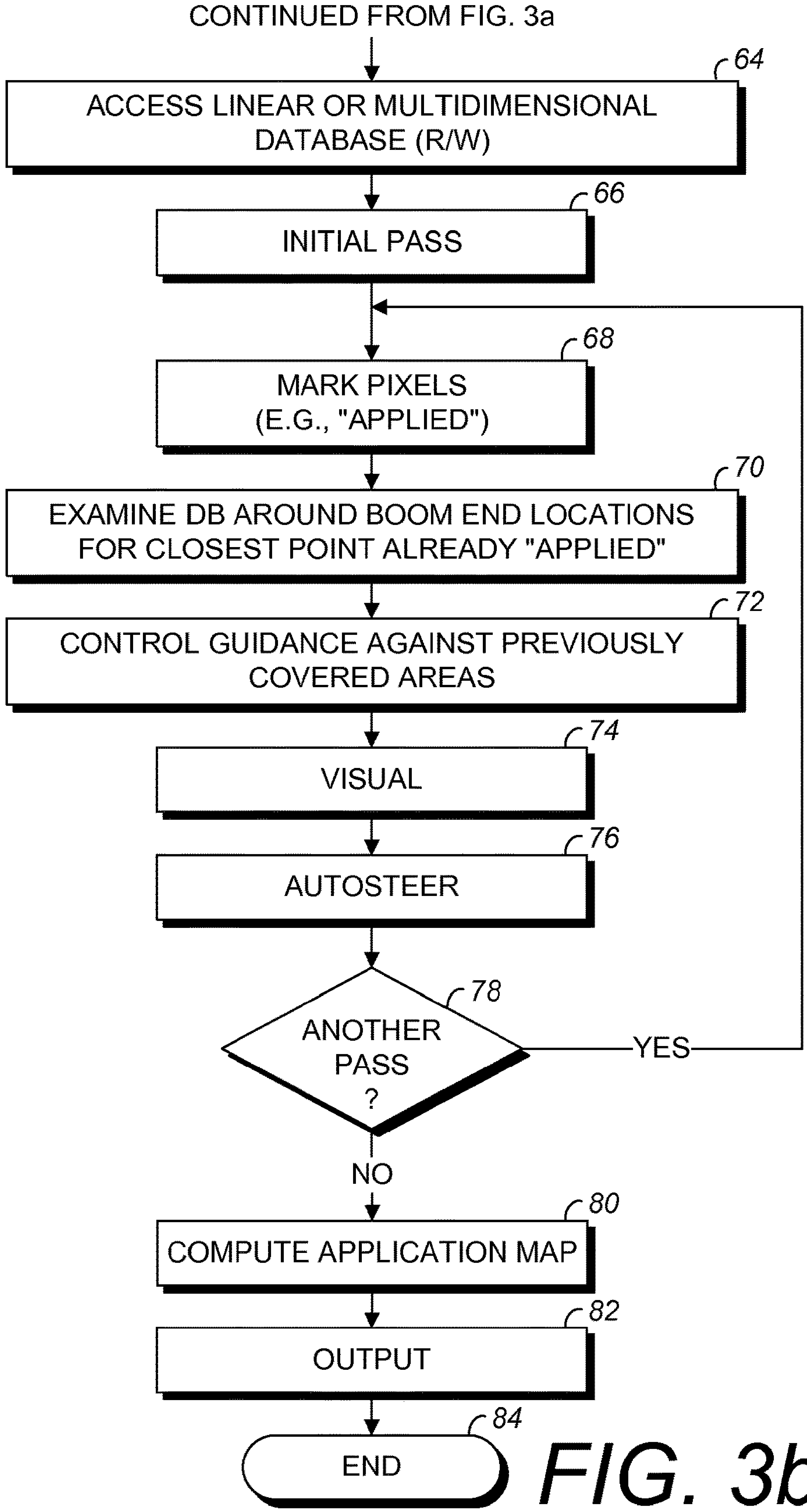

CONTINUED FROM FIG. 3a
64
ACCESS LINEAR OR MULTIDIMENSIONAL DATABASE (R/W)
66
INITIAL PASS
68
MARK PIXELS (E.G., "APPLIED")
70
EXAMINE DB AROUND BOOM END LOCATIONS FOR CLOSEST POINT ALREADY "APPLIED"
72
CONTROL GUIDANCE AGAINST PREVIOUSLY COVERED AREAS
74
VISUAL
76
AUTOSTEER
78
ANOTHER PASS ?
YES
NO
80
COMPUTE APPLICATION MAP
82
OUTPUT
84
END

FIG. 3b

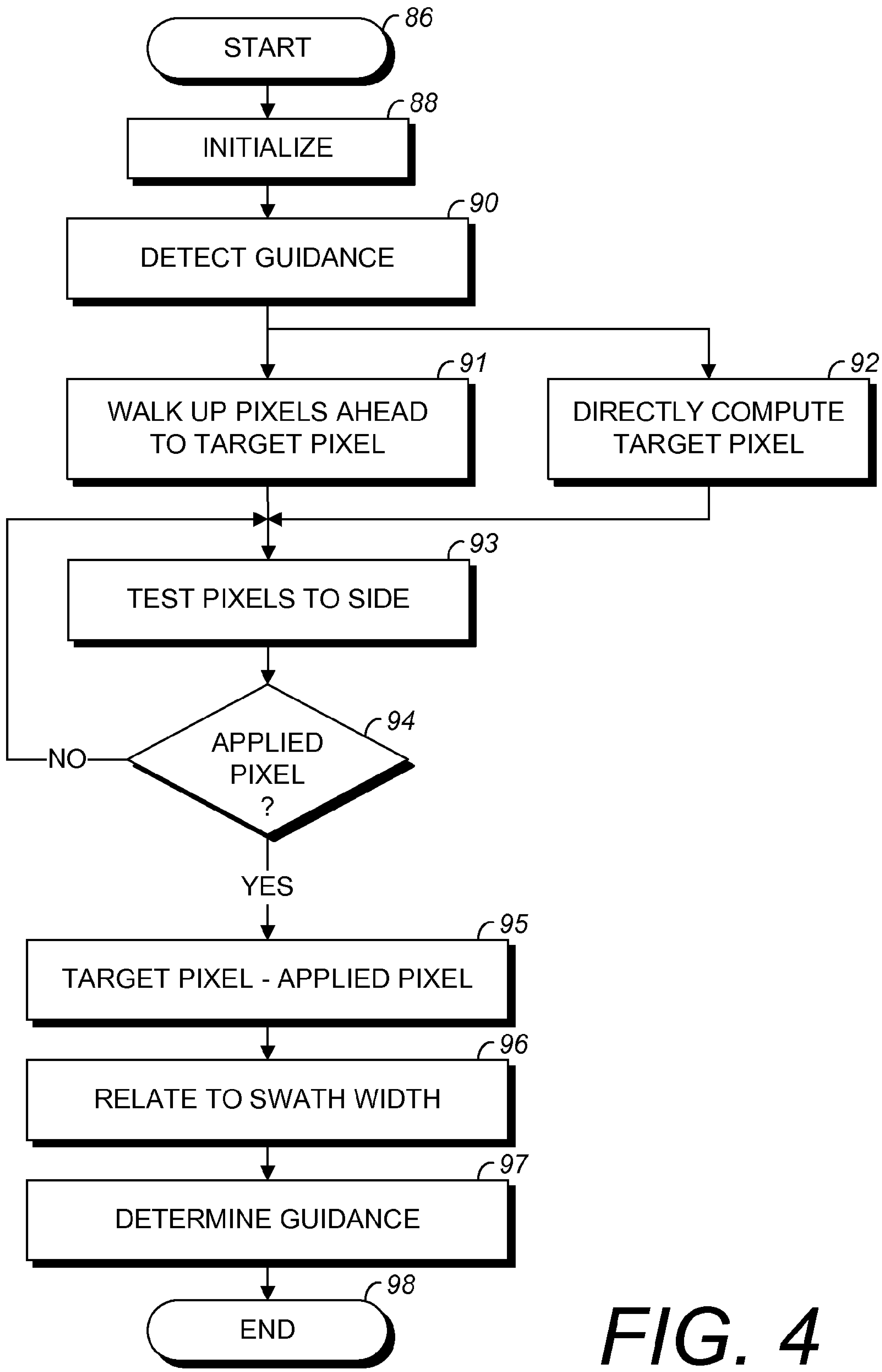

START
86
INITIALIZE
88
DETECT GUIDANCE
90
WALK UP PIXELS AHEAD TO TARGET PIXEL
91
DIRECTLY COMPUTE TARGET PIXEL
92
TEST PIXELS TO SIDE
93
APPLIED PIXEL ?
94
NO
YES
TARGET PIXEL - APPLIED PIXEL
95
RELATE TO SWATH WIDTH
96
DETERMINE GUIDANCE
97
END
98

FIG. 4

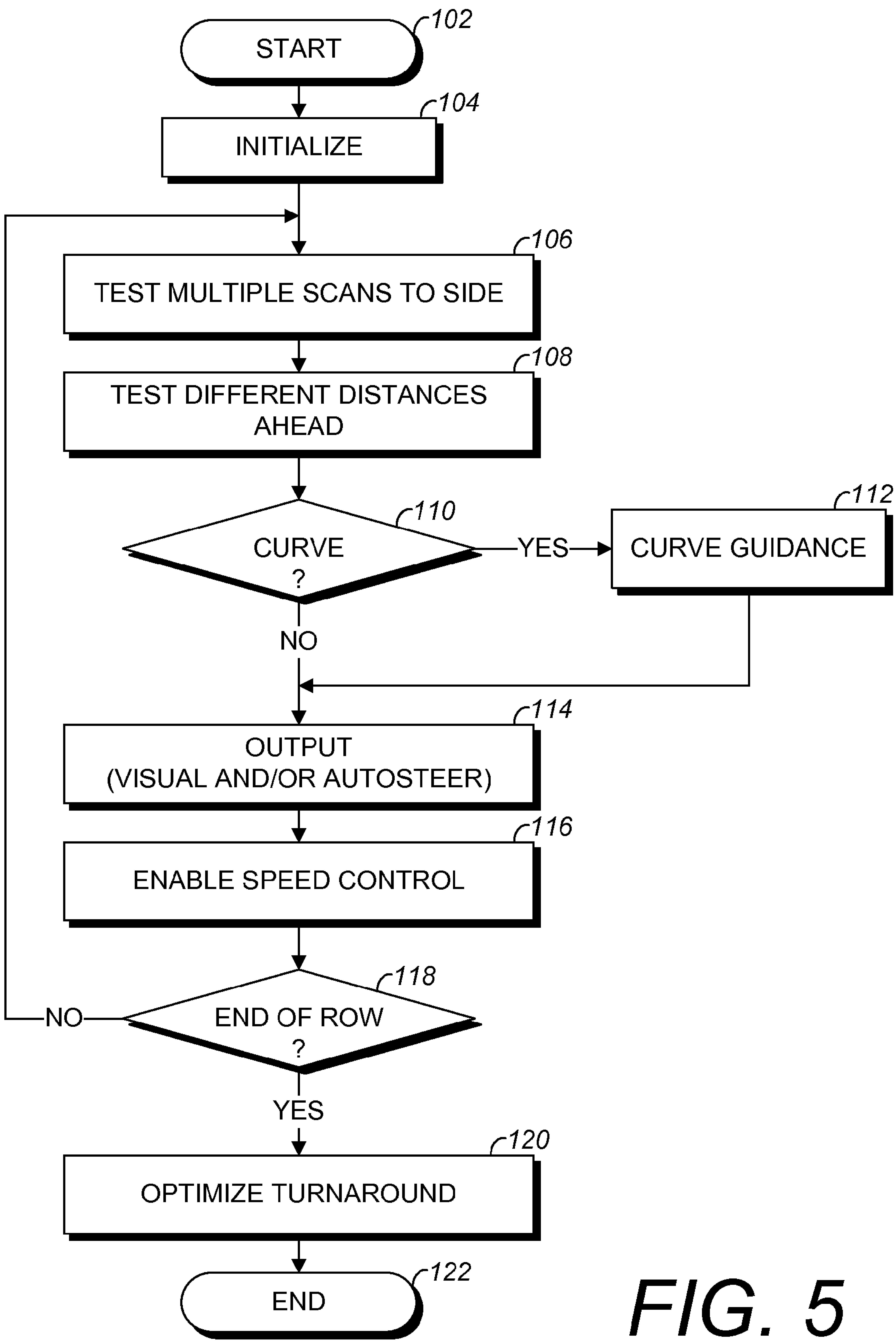

102
START
104
INITIALIZE
106
TEST MULTIPLE SCANS TO SIDE
108
TEST DIFFERENT DISTANCES AHEAD
110
CURVE ?
YES
112
CURVE GUIDANCE
NO
114
OUTPUT (VISUAL AND/OR AUTOSTEER)
116
ENABLE SPEED CONTROL
118
END OF ROW ?
NO
YES
120
OPTIMIZE TURNAROUND
122
END

FIG. 5

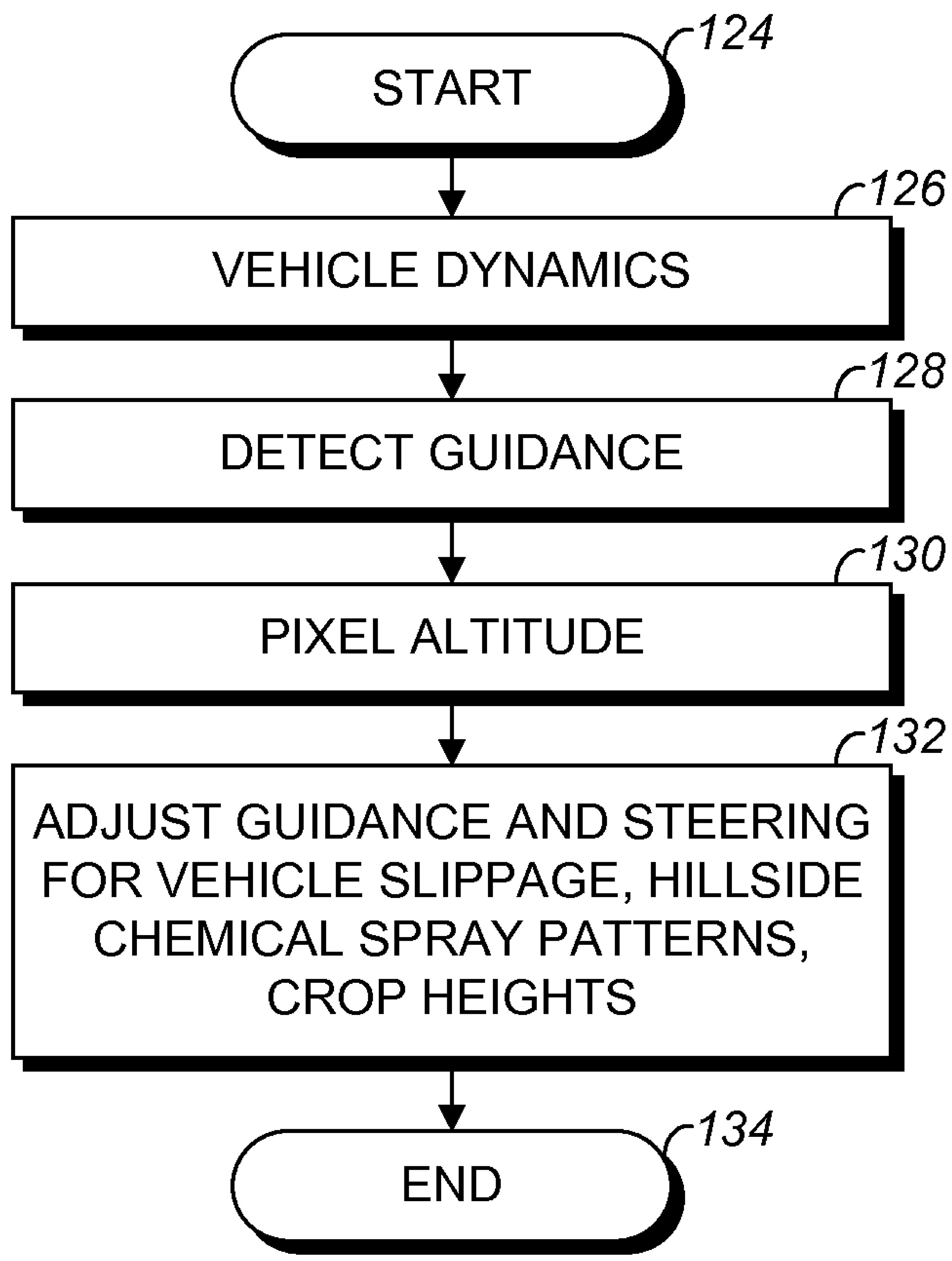

124
START
126
VEHICLE DYNAMICS
128
DETECT GUIDANCE
130
PIXEL ALTITUDE
132
ADJUST GUIDANCE AND STEERING FOR VEHICLE SLIPPAGE, HILLSIDE CHEMICAL SPRAY PATTERNS, CROP HEIGHTS
134
END

FIG. 6

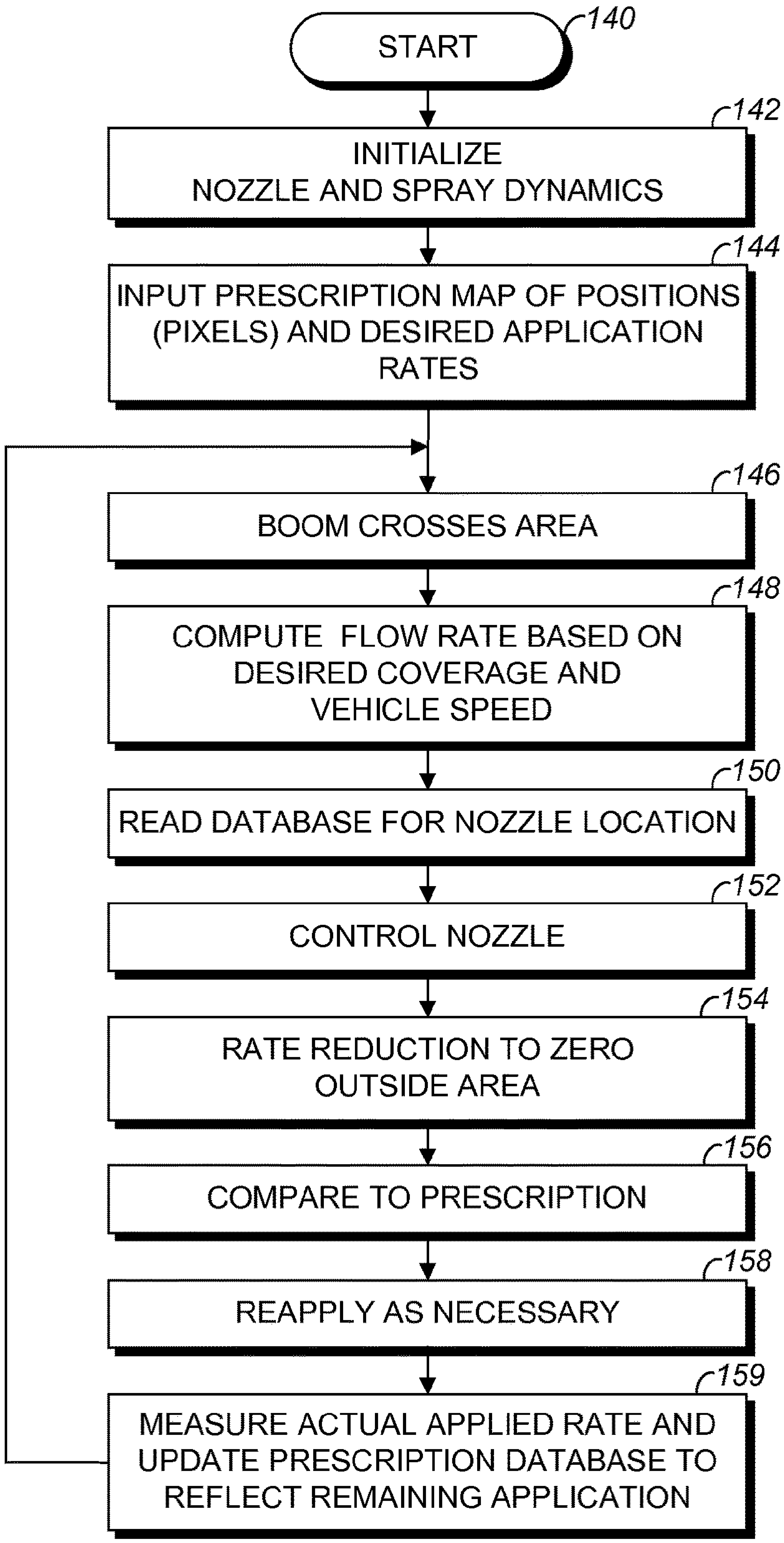

START
140
INITIALIZE
NOZZLE AND SPRAY DYNAMICS
142
INPUT PRESCRIPTION MAP OF POSITIONS (PIXELS) AND DESIRED APPLICATION RATES
144
BOOM CROSSES AREA
146
COMPUTE FLOW RATE BASED ON DESIRED COVERAGE AND VEHICLE SPEED
148
READ DATABASE FOR NOZZLE LOCATION
150
CONTROL NOZZLE
152
RATE REDUCTION TO ZERO OUTSIDE AREA
154
COMPARE TO PRESCRIPTION
156
REAPPLY AS NECESSARY
158
MEASURE ACTUAL APPLIED RATE AND UPDATE PRESCRIPTION DATABASE TO REFLECT REMAINING APPLICATION
159

FIG. 7

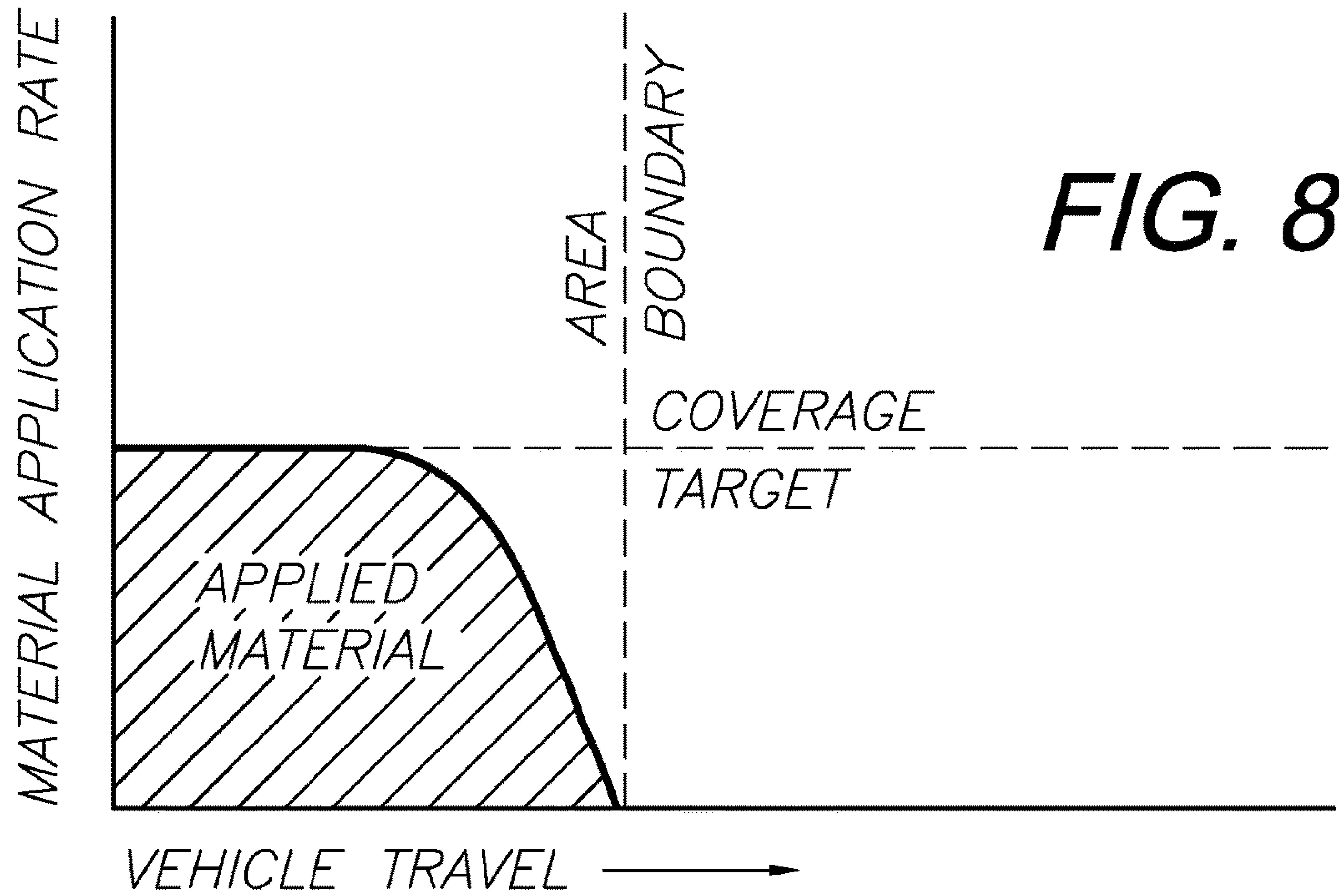

MATERIAL APPLICATION RATE
AREA BOUNDARY
COVERAGE TARGET
APPLIED MATERIAL
VEHICLE TRAVEL

FIG. 8a

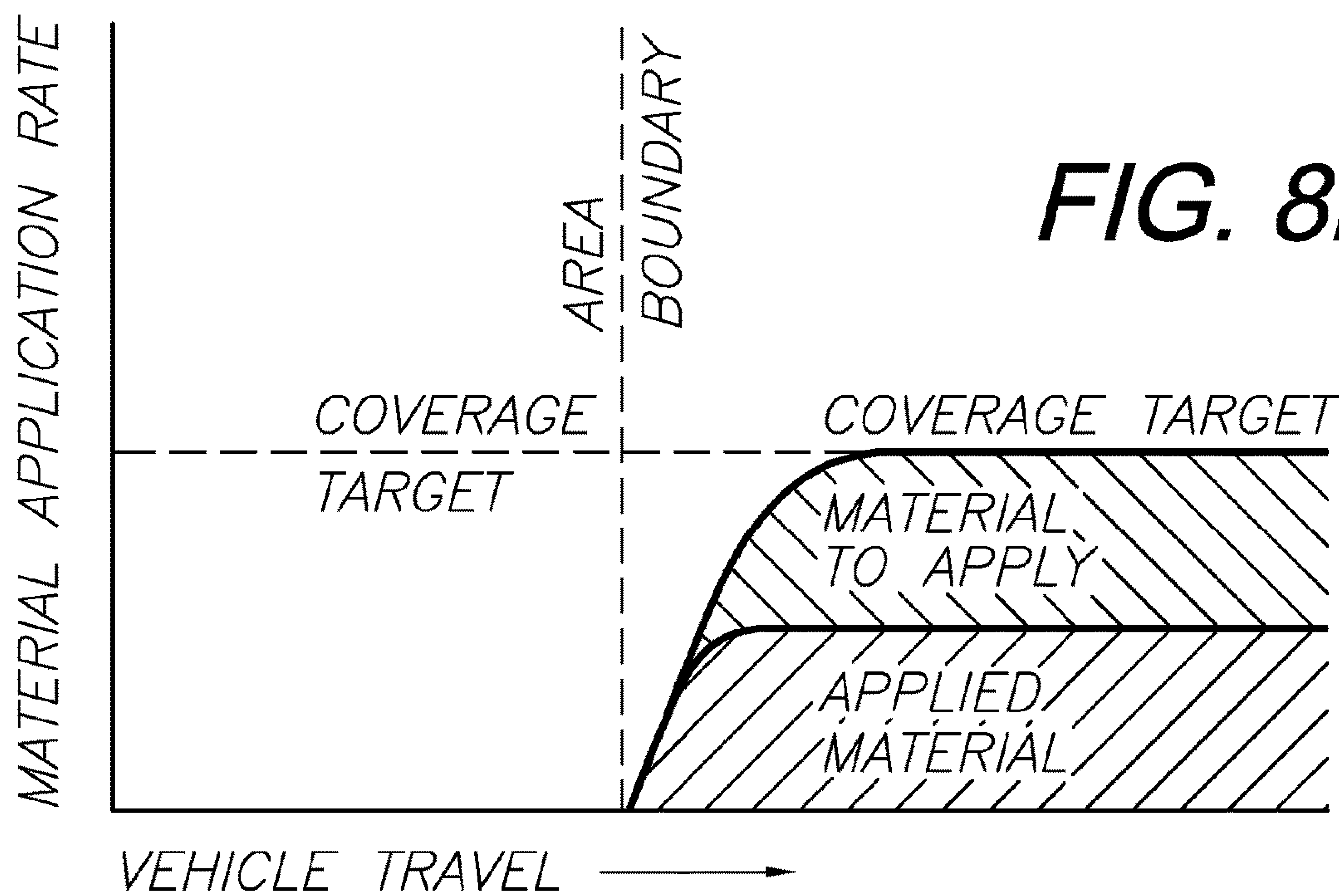

MATERIAL APPLICATION RATE
AREA BOUNDARY
COVERAGE TARGET
COVERAGE TARGET
MATERIAL TO APPLY
APPLIED MATERIAL
VEHICLE TRAVEL

FIG. 8b

RASTER-BASED CONTOUR SWATHING FOR GUIDANCE AND VARIABLE-RATE CHEMICAL APPLICATION

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS-REFERENCE TO RELATED APPLICATIONS

[This application is a continuation of and claims priority in U.S. patent application Ser. No. 12/689,184, filed Jan. 18, 2010, now U.S. Pat. No. 8,386,129, issued Feb. 26, 2013, which claims priority in U.S. Provisional Patent Application Ser. No. 61/145,542, filed Jan. 17, 2009, both of which are incorporated herein by reference.] *This application is a reissue of U.S. patent application Ser. No. 13/776,512, filed Feb. 25, 2013, now U.S. Pat. No. 8,718,874, issued May 6, 2014, which is a continuation of and claims priority to U.S. patent application Ser. No. 12/689,184, filed Jan. 18, 2010, now U.S. Pat. No. 8,386,129, issued Feb. 26, 2013, which claims priority in U.S. Provisional Patent Application Ser. No. 61/145,542, filed Jan. 17, 2009, all of which are incorporated by reference in their entireties.*

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to automated equipment control using a raster-based database, including vehicle navigation and guidance using global navigation satellite system (GNSS), inertial navigation system (INS) and other positioning inputs, and machine control functions such as variable-rate chemical applications in agricultural spraying.

2. Description of the Related Art

GNSS technology advanced vehicle and machine guidance and control in various technical fields, including the field of agricultural guidance by enabling reliable, accurate systems, which are relatively easy to use. GNSS guidance systems are adapted for displaying directional guidance information to assist operators with manually steering the vehicles. For example, the OUTBACK® steering guidance system, which is available from Hemisphere GPS LLC of Calgary, Alberta, Canada and is covered by U.S. Pat. Nos. 6,539,303 and 6,711,501 (incorporated herein by reference), includes an on-board computer capable of storing various straight-line and curved ("contour") patterns. An advantage of this system is its ability to retain field-specific cultivating, planting, spraying, fertilizing, harvesting and other patterns in memory. This feature enables operators to accurately retrace such patterns. Another advantage relates to the ability to interrupt operations for subsequent resumption by referring to system-generated logs of previously treated areas. The OUTBACK S steering guidance system, and related product offerings from Hemisphere GPS LLC, utilize "near point search method" technology, which logs GPS-defined positions along swath edges, the nearest of which are located for placing the edge of the next swath against the last.

Another type of GPS guidance utilizes "form line following," wherein vectors, which can be straight-line (A-B) or curved (contour), are computed based on equipment widths

offset from the previously-driven form lines. A disadvantage with this type of system is that initial form lines must be driven and delineated based upon which subsequent form lines must be computed and followed. Significant computer overhead can be occupied with such tasks, whereby trade-offs are required between component costs and system responsiveness.

GNSS vehicle guidance equipment using the above techniques is available as a steering guide with a graphical user interface (GUI) for manually-steered vehicles, and also with an autosteer function for automatically steering the vehicle along all or part of its travel path. Automated systems can also control an agricultural procedure or operation, such as spraying, planting, tilling, harvesting, etc. Examples of such equipment are shown in U.S. Pat. No. 7,142,956, which is incorporated herein by reference. U.S. Patent Application Publication No. 2004/0186644 shows satellite-based vehicle guidance control in straight and contour modes, and is also incorporated herein by reference. U.S. Pat. No. 7,162,348 is incorporated herein by reference and discloses an articulated equipment position control system and method whereby a working component, such as an implement, can be guided independently of a motive component, such as a tractor. The implement can optionally be equipped with its own GNSS antenna and/or receiver for interacting with a tractor-mounted GNSS system.

Ideally crops would be planted in perfectly straight, evenly-spaced rows. Guidance through such fields would consist of following relatively simple straight-line patterns. Such guidance modes are commonly referred to as straight line or "A-B" in reference to the equipment traveling in a straight line from point A to point B in a repeating pattern in order to cover an entire field, which is typically flat and rectangular and therefore efficiently divided into multiple, parallel swaths. However, field conditions in many areas are not suitable for A-B guidance. For example, hilly terrain sometimes requires the formation of constant-elevation terraces.

Guidance systems accommodate such irregular conditions by operating in "contour following" modes consisting of curvilinear tracks defined by multiple GNSS points along which the equipment is guided. Initial planting passes made with manual and visually-guided navigation, which may or may not be supplemented with GNSS navigational aids, can cause crop rows to deviate from straight lines. Accommodating such irregular crop rows in subsequent operations (e.g., spraying and harvesting) may require the equipment to deviate from straight-line passes.

"Tramline" (sometimes referred to as "match tracks") is another operating mode available with some modern GNSS guidance systems. In tramline operating mode the existing crop rows are relatively well protected because the equipment follows or "matches" the previously-driven passes. The equipment wheels or tracks are thus confined between the crop rows. Machine damage from running over crops is thus avoided, or at least minimized.

Preferably a system embodying an aspect of the present invention would avoid the drawbacks inherent in the previous systems described above and be adaptable to various machine control applications, including variably controlling the output of individual nozzles in agricultural sprayers. In particular, raster (e.g., bitmap) data bases can be used with previously-defined world geodetic systems, such as WGS 84, thereby eliminating overhead-intensive tasks such as continuously running extensive searches for points along the edges of previously-driven swaths or computing form lines.

Heretofore there has not been available a raster-based contour swathing system and method with the advantages and features of the present invention.

SUMMARY OF THE INVENTION

In the practice of the present invention, a system and method are provided for automatically guiding and controlling vehicles and equipment using GNSS for defining a raster-based database of pixels defining either an entire area to be treated, or a subset through which a vehicle travels. For example, agricultural equipment comprising a tractor and an implement can be equipped with a vector position and heading sensor subsystem including a GNSS receiver and antennas and an optional inertial navigational system (INS) with X, Y and Z axis sensors for sensing equipment attitude changes through six degrees of freedom. Such sensors typically comprise gyroscopes and/or accelerometers. A 2D map array comprises an XY grid of pixels, which is scalable according to the requirements of a particular operation. Guidance operations are accomplished by marking pixels as "applied" when treated on an equipment pass. Subsequent passes can guide off of the applied pixel areas, using "target" aim point pixels and/or swath-width spacing to one side or the other of the applied areas. Moreover, machine control functions can actuate certain operations based on equipment position. For example, spray nozzles on a sprayer implement can be selectively and individually actuated over areas to be sprayed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of agricultural equipment equipped with GNSS and (optionally) INS guidance and control systems, shown in operation on a field defined by an XY array of pixels.

FIG. **2** is a block diagram of a GNSS/INS/RTK tractor and implement system for implementing the raster-based guidance system and method.

FIGS. **3**a and **3**b show a flowchart of a raster-based guidance method.

FIG. **4** is a flowchart of another aspect of the raster-based guidance method using target pixels.

FIG. **5** is a flowchart of another aspect of the raster-based guidance method.

FIG. **6** is a flowchart of another aspect of the raster-based guidance method.

FIG. **7** is a flowchart of another aspect of the raster-based guidance method including spray nozzle control.

FIG. **8**a is a diagram of material application parameters on exiting a treated area.

FIG. **8**b is another diagram of material application parameters on entering an area to be treated.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

I. Introduction and Environment

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which may be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure.

Certain terminology will be used in the following description for convenience in reference only and will not be limiting. For example, up, down, front, back, right and left refer to the invention as oriented in the view being referred to. The words "inwardly" and "outwardly" refer to directions toward and away from, respectively, the geometric center of the embodiment being described and designated parts thereof Global navigation satellite systems (GNSS) are broadly defined to include GPS (U.S.), Galileo (proposed), GLONASS (Russia), Beidou (China), Compass (proposed), IRNSS (India, proposed), QZSS (Japan, proposed) and other current and future positioning technology using signals from satellites, using single or multiple antennae, with or without augmentation from terrestrial sources. Inertial navigation systems (INS) include gyroscopic (gyro) sensors, accelerometers and similar technologies for providing output corresponding to the inertia of moving components in all axes, i.e. through six degrees of freedom (positive and negative directions along transverse X, longitudinal Y and vertical Z axes). Yaw, pitch and roll refer to moving component rotation about the Z, X and Y axes respectively. Said terminology will include the words specifically mentioned, derivatives thereof and words of similar meaning.

II. Guidance and Control System 4

Referring to the drawings in more detail, the reference numeral **2** generally designates a piece of agricultural equipment, which is equipped with a raster-based guidance and control system **4** embodying an aspect of the present invention. Without limitation on the generality of equipment **2**, a motive component **6** is connected to a working component **7** through an optional articulated connection or hitch **34** (collectively comprising the equipment or vehicle **2**). Also by way of example, the motive component **6** can comprise a tractor or other vehicle and the working component **7** can comprise a ground-working implement. However, the system **4** can be applied to other equipment configurations for a wide range of other applications. Such applications include equipment and components used in road construction, road maintenance, earthworking, mining, transportation, industry, manufacturing, logistics, etc.

FIG. **1** shows the equipment **2** operating on a portion of a field **10** with an array of XY pixels **50**, which are used for providing guidance and controlling the operation of the implement **7**, which can comprise a sprayer with individual nozzles **8**.

FIG. **2** is a schematic block diagram showing the components of the GNSS guidance/control system **4**. The tractor **6** components include a GNSS receiver **12** including a first vehicle antenna **21**, an optional second vehicle antenna **22**, an RF (down) converter **14**, a tracking device **16** and an optional rover RTK receiver **18**. A guidance processor CPU **23** includes a GUI display **24**, a microprocessor **26** and a media storage device **28**. Vehicle steering **30** and INS components **31** (e.g., gyroscopes and/or accelerometers) are connected to the guidance processor **23**. GNSS-derived data is transferred from the GNSS receiver **12** to the guidance processor CPU **23**. The implement **7** can include a first implement antenna **41** and an optional second implement antenna **42**, which are connected to the vehicle GNSS receiver **12** and provide GNSS data thereto.

An implement steering subsystem **36** receives steering commands from the guidance processor CPU **23** via a CAN bus **32** or some other suitable connection, which can be wireless. The implement **7** is mechanically connected to the vehicle **6** by a hitch **34**, which can be power-driven for active implement positioning in response to implement steering commands, or a conventional mechanical linkage. The hitch

34 can be provided with sensors for determining relative attitudes and orientations between the vehicle **6** and the implement **7**. Examples of such an articulated connection and an implement steering system are described in U.S. Pat. Nos. 6,865,465, 7,162,348 and 7,460,942, which are incorporated herein by reference. The implement **8** can comprise any of a wide range of suitable implements, such as planting, cultivating, harvesting and spraying equipment. For example, spraying applications are commonly performed with a boom **5**, which can be equipped for automatic, selective control of multiple nozzles **8** and other boom operating characteristics, such as height, material dispensed, etc. By way of example and without limitation, the implement **7** can comprise an agricultural sprayer with a spray nozzle control **38** connected to the guidance processor CPU **23** by the CAN bus **32** for individually controlling the spray nozzles **8**.

The GNSS/INS guidance and control system **4** can be configured in various combinations of components and thereby accommodate a wide range of guidance and control operations. For example, RTK guidance can be accommodated with a base **44** including an RTK receiver **46** and an RTK transmitter **48**, which can be mounted at a fixed-position reference point in the general vicinity of fields being worked by the equipment **2**. Moreover, various combinations of receivers and antennas can be used on the vehicle **6** and/or the implement **7**, including single frequency (L1 only) and dual frequency (L1 and L2). Various forms of signal correction can also be utilized, including Satellite Based Augmentation System (SBAS), Wide Area Augmentation System (WAAS) and private subscription services.

The GNSS receiver **12** disclosed herein can be adapted for various satellite navigational systems, and can utilize a variety of SBAS technologies. Technology is also available for continuing operation through satellite signal interruptions, and can be utilized with the system **4**. The antennas **21**, **22** can be horizontally aligned transversely with respect to a direction of travel of the tractor **6**, i.e. parallel to its transverse X axis. The relative positions of the antennas **21**, **22** with respect to each other can thus be processed for determining yaw, i.e. rotation with respect to the vertical Z axis. The INS **31** can include inertial sensors (e.g., gyroscopes and accelerometers) for detecting and measuring inertial movement with respect to the X, Y and Z axes corresponding to yaw, roll and pitch movements in six degrees of freedom. Signals from the receiver **12** and the INS sensors are received and processed by the microprocessor **26** based on how the system **4** is configured and programmed

III. Raster-based Guidance and Control Method

FIGS. **3**a and **3**b show a method of raster-based guidance and control according to an aspect of the present invention. From a start **40** the system **4** is initialized at **42**, including setting a pixel grid resolution at **44**. Without limitation, pixel grid resolution in the approximate range of 0.05 meters to 5 meters can be useful for various operations, depending on the desired accuracy.

Setup of a raster-based database (DB) of XY pixel grid pages **48** occurs at **46**. An example of a pixel grid page **48** is shown in FIG. **1** and includes multiple pixels **50**. Pixel grid pages can cover entire fields, or, alternatively from decision box **51**, can be freeform and automatically expandable in any direction through a tiling method at step **52**. An exemplary preferred method is to use a rectangular grid based on WGS 84 comprising GPS-based coordinates for generating a grid page at **48**. Scale factors for latitude and longitude are set at **56** and an initial reference point is defined at **58**. A location in the grid area can be generated at **60** on a GIS system, such as the Map Star™ program available from Hemisphere GPS of Calgary, Alberta, Canada, or in real-time in the field on the guidance system **4**. Locations in the grid area are defined by the number of pixels east-west (EW) and north-south (NS) from the reference location at **62**. *X and Y pixel indicies are computed in 62 where X and Y indicies=(Current Position−Reference position).* A linear or multidimensional database is accessed at **64** using the XY pixel indices computed at **62**. The database can be accessed and read and/or written to (R/W) at **64**.

In an exemplary field spraying operation using the sprayer **7**, the equipment **2** is driven in an initial pass at **66** in a "swath" mode with its swath width comprising one of the operating parameters whereby all pixels covered by the spray boom **5** are marked as "applied" (**50**a in FIG. **1**) at step **68**. On a subsequent adjacent pass, the database around the spray boom end locations is examined for the closest applied pixel **50**a at **70**, which is designated **50**d (tested and applied) in FIG. **1**, and is then used for instantaneous guidance control at **72**, either through a visual GUI at **74** and/or an autosteering function at **76**.

As shown in FIG. **1**, the operator can thereby drive against previously covered (applied) pixels **50**a. The database can be programmed for "unapplied" **50**e and "applied" **50**a pixel status conditions. Other pixel status conditions can include "vehicle track" **50**b, "unapplied test" **50**c, "applied test" **50**d, "unapplied" **50**e, "under-applied" **50**f and "over-applied" **50**g (FIG. **1**). The process continues via a loop through the "another pass" decision box **78** until complete or interrupted, whereafter an application map showing database values, pixel status, equipment positions and headings is computed at **80** and output at **82** with the operation ending at **84**.

FIG. **4** shows another method of guidance using the vehicle **6** location, swath (e.g., spray boom **5**) width and direction of travel. From start **86**, initialize **88** and detect guidance **90**, vehicle track/target pixels **50**b (FIG. **1**) ahead of the equipment **2** are "walked up" from the center of the vehicle **6** to a *target pixel* point ahead using either a Bresenham-type algorithm at **91** or by directly computing a track/target pixel **50**b ahead at **92**. Then the unapplied test pixels **50**c to the side of the track/target pixel **50**b are tested for "applied" status at **93**. Upon detecting an applied test pixel **50**d at **94**, its distance away from the track/target pixel **50**b relative to the implement swath width (i.e. "offset" generally equal to half of the swath width) is obtained at **95**, related to swath width at **96**, used to determine guidance at **97** and the method ends at **98**.

As shown in FIG. **5**, a similar method can be used for computing guidance using two dimensions (2D). From start **102** and initialize **104**, multiple scans to the side of the vehicle and different distances ahead of it are tested at **106**, **108** respectively to detect previously-applied areas along curves at **110** and to implement curve guidance at **112**. The output can be provided visually via a GUI **24** and/or used in an autosteering algorithm at **114**. Speed control at **116** and end-of-row turnaround at **118**, **120** can be enabled and optimized. The method ends at **122**.

FIG. **6** shows a variation comprising a 3D method using the altitudes of the different pixels for adjusting guidance and steering. From a start **124** vehicle dynamics are input as operating parameters at **126**, guidance is detected at **128** and pixel altitudes are input at **130**. For example, the method can compensate by remaining closer to the applied area to adjust for vehicle downhill slippage and hillside chemical spray patterns at **132**. Such 3D information can also correspond to crop heights with the system making suitable adjustments, also at **132**. The method ends at **134**.

FIG. **7** shows another method of the invention involving sprayer nozzle control. From a start **140** the nozzle and spray dynamics are initialized at **142**. A chemical spray prescription map including the positions represented by pixels and target chemical application rates (e.g. gallons per acre) is input at **144**. Operation commences as the spray boom crosses an area at **146** and flow rate is computed based on desired coverage (i.e. prescription database value) and vehicle speed at **148**. The database is read for the locations of the spray nozzles at **150** whereby their pixel-defined locations are used for determining chemical applications and nozzle control at **152**. At **154** the dispensing rate for one or more of the nozzles **8** is reduced to zero if the equipment **2** travels outside the predetermined application area, e.g., field **10**. A comparison with the prescription occurs at **156** followed by reapplication as necessary at **158** followed by measure actual applied rate and update prescription database to reflect remaining application at **159** followed by a loop back to **146**. The process shown in FIG. **7** is continuous in the sense that the operator can start and stop at any time and the sprayer will only dispense when located over a pixel **50** with a non-zero prescription database value. Thus, the field **50** is completely treated when all of its pixels **50** have zero prescription database values, and the system will no longer dispense.

In conjunction with the methods described above, variable rate control can be accomplished using multiple channels for individual nozzle control of chemical applications. For example, the CAN bus **32** communicates individual nozzle control commands from the processor **23** to the spray nozzles **8**, which can be monitored and boom pressure controlled thereby for correct calibration. Individual nozzle flow rate control across the entire spray boom accommodates swath overlaps whereby spray nozzle output would be reduced or shut off. Nozzles **8** can also be shut off upon entry into previously-applied areas and no-spray areas, such as outside the field boundaries.

The pixel status in the method of the present invention includes information on the chemical(s) application rates(s). As the spray boom **5** crosses the treatment area the database is read for each nozzle **8** location and the desired rates per area, e.g. gallons per acre. The nozzle flow rate is then adjusted to the required output, e.g., in gallons per minute (GPM) based on the current nozzle speed. The amount of coverage during turning of the vehicle can also vary according to the nozzle locations in the turn, with the outermost nozzle **8** traveling fastest (requiring the greatest flow rate) and the innermost nozzle traveling slowest (requiring the least flow rate). Such speeds can vary considerably in turns and are accommodated by the system **4**.

Alternative algorithms can be utilized for managing chemical application. For example, in a "rate reduction to zero" algorithm the application rates can be progressively reduced on one or more passes as required to "zero out" the applied material quantities across the boom widths whereby on subsequent passes the applied rate will be zero gallons per acre. Alternatively, in an "as applied map" algorithm the application rates can be read back in real time from the processor **23** and subtracted from the desired target rate per pixel and written back as the remaining desired rates with a flag indicating partial application marking the partially-treated (under-applied) pixels **50**f. The real time database display reflects the remaining rates required for each pixel, the remaining chemical required for the completion of the field area and the remaining quantities available.

Various output information can be provided to an operator, e.g., indicating pixel status originally and currently, "as applied" mapping and remaining chemical application rates by pixel for job completion. By individually controlling the flow rates at the nozzles **8**, the desired prescription map area rate can be achieved, thereby optimizing variable rate coverage for increased crop production. Less-experienced operators can be accommodated because the system **4** reduces the likelihood of over-application or application outside the field perimeter.

FIGS. **8**a and **8**b show conditions encountered at field perimeters (i.e. area boundaries). FIG. **8**a shows a preemptive shut off as the vehicle approaches the area boundary. Programming the system **4** with such "look-ahead" capabilities can prevent chemical application beyond the area boundary. FIG. **8**b shows commencing application upon entering a coverage area, which can occur in phases with a first applied material quantity, from which the remaining quantity of material to be applied can be determined in order to achieve the target chemical application.

It is to be understood that the invention can be embodied in various forms, and is not to be limited to the examples discussed above. *The different methods described above may be combined together.*

What is claimed and desired to be secured by Letters Patent is as follows:

1. A method of *using a processor for* guiding an agriculture [sprayer] vehicle including a motive component and a [spray] *working* component [with a spray boom having opposite ends and multiple spray nozzles mounted in spaced relation between said ends, said components being interconnected by a power hitch adapted for laterally shifting said working component relative to said motive component, which method comprises the steps of]*, comprising*:

providing an XY pixel grid *page* corresponding to [the] *an* area*, the grid page including pixels associated with different portions of the area*;

[providing a raster-based database page comprising said XY pixel grid for said area;

providing a processor on the vehicle;

providing a GNSS guidance system connected to the processor on the vehicle;

receiving GNSS positioning signals with said guidance system;

providing said GNSS positioning signals as input to said processor;

computing GNSS-based positioning for said vehicle with said processor;

defining a GNSS-defined reference point on said area and storing the reference point coordinates with said processor;

computing X and Y pixel indices based on said GNSS-defined vehicle position in relation to said reference point with said processor;

treating portions of said area with said working component;

with said processor marking pixels in said treated area portions as treated;

guiding said vehicle over said area utilizing said treated pixel information;

defining additional raster-based XY pixel grid pages in said area;

expanding said database by tiling said pixel grid pages over said area;

generating X and Y scale factors for said database;

relating said X and Y scale factors to latitude and longitude respectively;

computing X and Y pixel indices based on the difference between current GNSS-defined position coordinates and the reference position coordinates;

creating with said processor a linear or multidimensional database comprising said pixel grid pages;

accessing with said processor said database;

marking pixels in said database as treated;

defining a swath coverage area with said working component ends forming opposite edges of said swath;

with said GNSS system and said processor seeking pixels in proximity to said swath edges;

with said GNSS system and said processor guiding said vehicle along said swath edges;

providing an autosteer system on said vehicle;

with said processor generating steering commands using the marked pixel information and said XY pixel page database;

outputting said steering commands to said autosteer system for automatically steering said vehicle over said area;

with said processor and said GNSS system laterally shifting said working component relative to said motive component for maintaining said working component generally within said swath;

computing an application map for said area corresponding to treatments of pixels therein with said working component;

guiding said vehicle with said application map while treating said pixels; and]

guiding the agricultural vehicle in an initial pass over the area corresponding to the grid page;

during the initial pass of the area marking the pixels in the XY pixel grid page associated with the portions of the area treated by the working component as applied pixels;

during another pass of the area, detecting a vehicle [direction of travel] *path* with [said] *a* GNSS system;

walking up [the] pixels in the *XY pixel grid page along the* vehicle [direction of travel] *path* to a target pixel *in the XY pixel grid page*;

testing *the* pixels [in multiple scans] *in the XY pixel grid page* alongside [said] *the* vehicle path for [treated conditions] *the applied pixels* based on a swath width of [said] *the* working component; *and*

guiding [said] *the* vehicle towards [said] *the* target pixel [using said treated condition pixel information] *based on the applied pixels identified* alongside [said] *the* vehicle path[;

testing multiple distances ahead for treated pixels;

detecting a curve condition defined by treated pixels;

guiding said vehicle alongside said curve using said treated pixel information;

preprogramming said processor with variables corresponding to vehicle performance dynamics;

determining altitudes of said pixels with said GNSS system; and

adjusting guidance and steering for vehicle slippage, sloping surface chemical spray patterns and crop heights using said vehicle performance dynamics and said pixel altitudes].

2. The method of claim 1, including:

testing, with the processor, multiple distances ahead for the applied pixels;

detecting, with the processor, a curve defined by the applied pixels; and

guiding, with the processor, the vehicle alongside the curve defined by the applied pixels.

3. The method of claim 1, including:

determining altitudes for the portions of the area;

assigning the altitudes to the pixels associated with the portions of the area; and

adjusting guidance and steering of the vehicle based on the altitudes assigned to the pixels associated with the portions of the area covered by the working component.

4. The method of claim 1, including:

defining additional XY pixel grid pages; and

combining the additional XY pixel grid pages with the provided XY pixel grid page.

5. The method of claim 1, including:

identifying a swath coverage area with swath edges corresponding with opposite ends of the working component;

identifying the pixels in proximity to the swath edges; and

steering the vehicle based on the pixels in proximity to the swath edges.

6. The method of claim 1, including:

assigning chemical prescription rate values to the pixels;

compute amounts of a chemical applied to the portions of the area;

compare the amounts of the chemical applied to the portions of the area with the chemical prescription rate values assigned to the pixels associated with the portions of the area; and

adjusting the amounts of additional chemical output from individual spray nozzles of the working component on the portions of the area based on the comparisons of the amounts of the chemical previously applied to the portions of the area and the chemical prescription rate values assigned to the pixels associated with the portions of the areas.

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