US008059030B2

(12) **United States Patent**
Oberg

(10) **Patent No.: US 8,059,030 B2**
(45) **Date of Patent: *Nov. 15, 2011**

(54) **METHOD AND SYSTEM FOR USING A DATABASE AND GPS POSITION DATA TO GENERATE BEARING DATA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 13 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/188,687**

(22) Filed: **Aug. 8, 2008**

(65) **Prior Publication Data**

US 2008/0297397 A1 Dec. 4, 2008

Related U.S. Application Data

(60) Division of application No. 10/818,900, filed on Apr. 6, 2004, now Pat. No. 7,428,450, which is a continuation-in-part of application No. 10/736,969, filed on Dec. 16, 2003, now Pat. No. 7,337,063.

(51) **Int. Cl.**
G01S 1/44 (2006.01)

(52) **U.S. Cl.** **342/404**

(58) **Field of Classification Search** 342/357.01–357.17, 401–406
See application file for complete search history.

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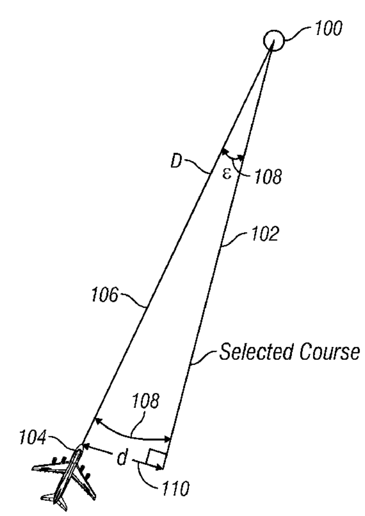
(57) **ABSTRACT**

A method and system for providing a bearing from a vehicle to a transmitting station are described. The method includes accessing a database to obtain transmitter position information for the transmitter, obtaining vehicle position information based on a GPS signal, and generating the bearing from the vehicle to the station utilizing the transmitter position information and the vehicle position information. The system includes a database storing transmitter position information identifying a position of the transmitter, a GPS receiver obtaining vehicle position information identifying a current position of the vehicle based on a GPS signal, and a controller generating a bearing from the vehicle to the transmitter utilizing the transmitter position information and the vehicle position information.

16 Claims, 9 Drawing Sheets



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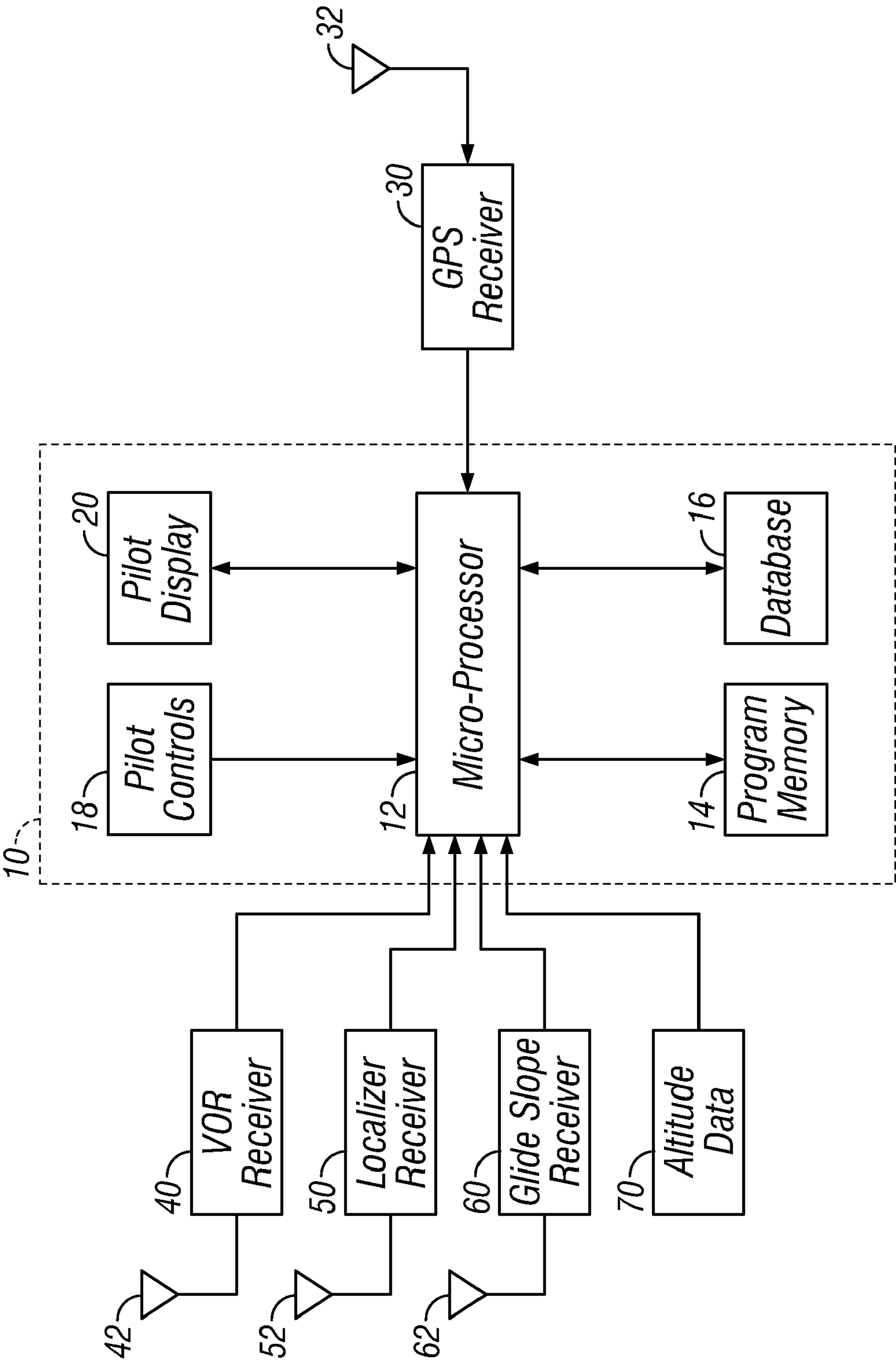
32
30
GPS Receiver
10
20
Pilot Display
18
Pilot Controls
12
Micro-Processor
16
Database
14
Program Memory
40
VOR Receiver
50
Localizer Receiver
60
Glide Slope Receiver
70
Altitude Data
42
52
62

FIG. 1

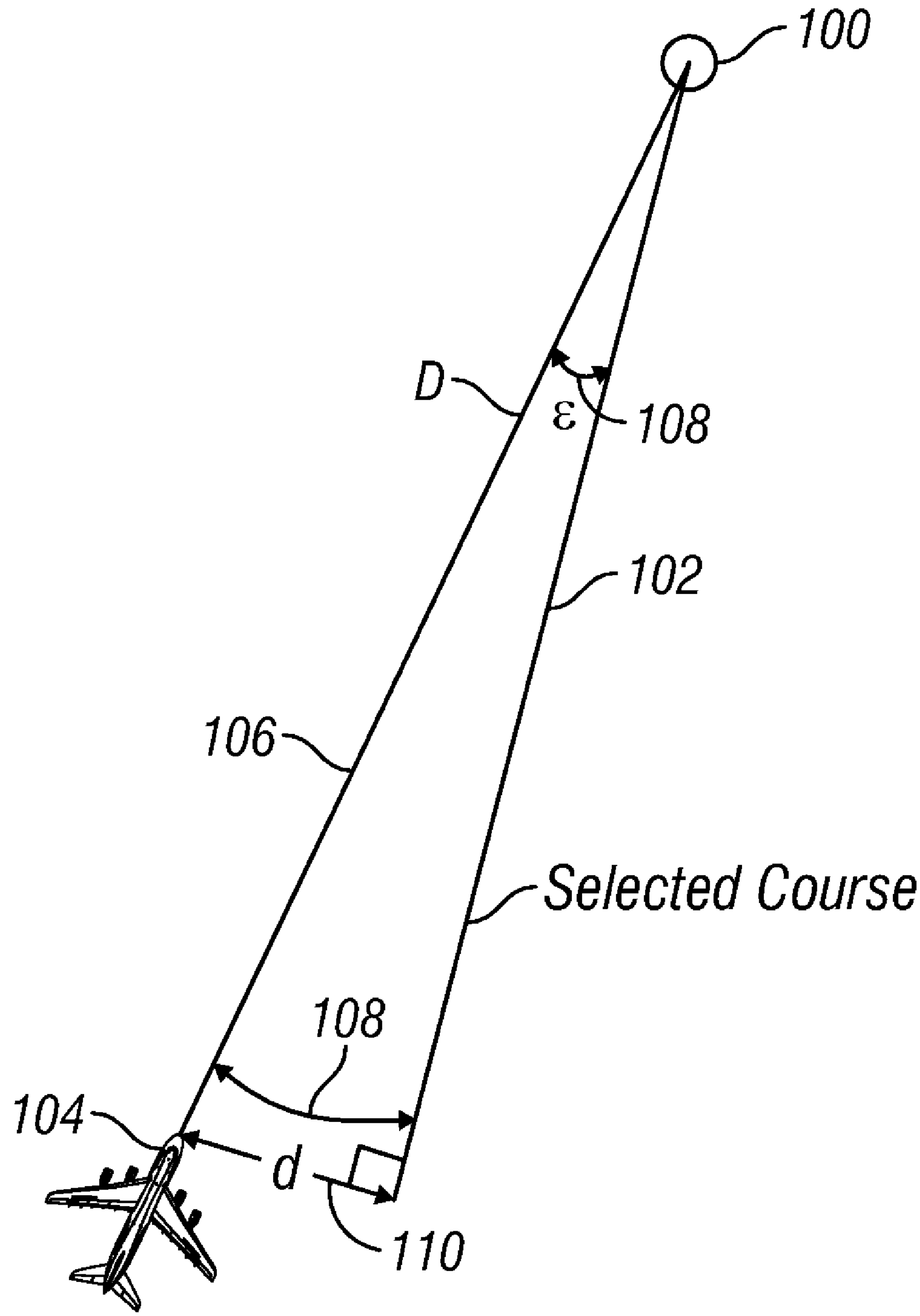

FIG. 2

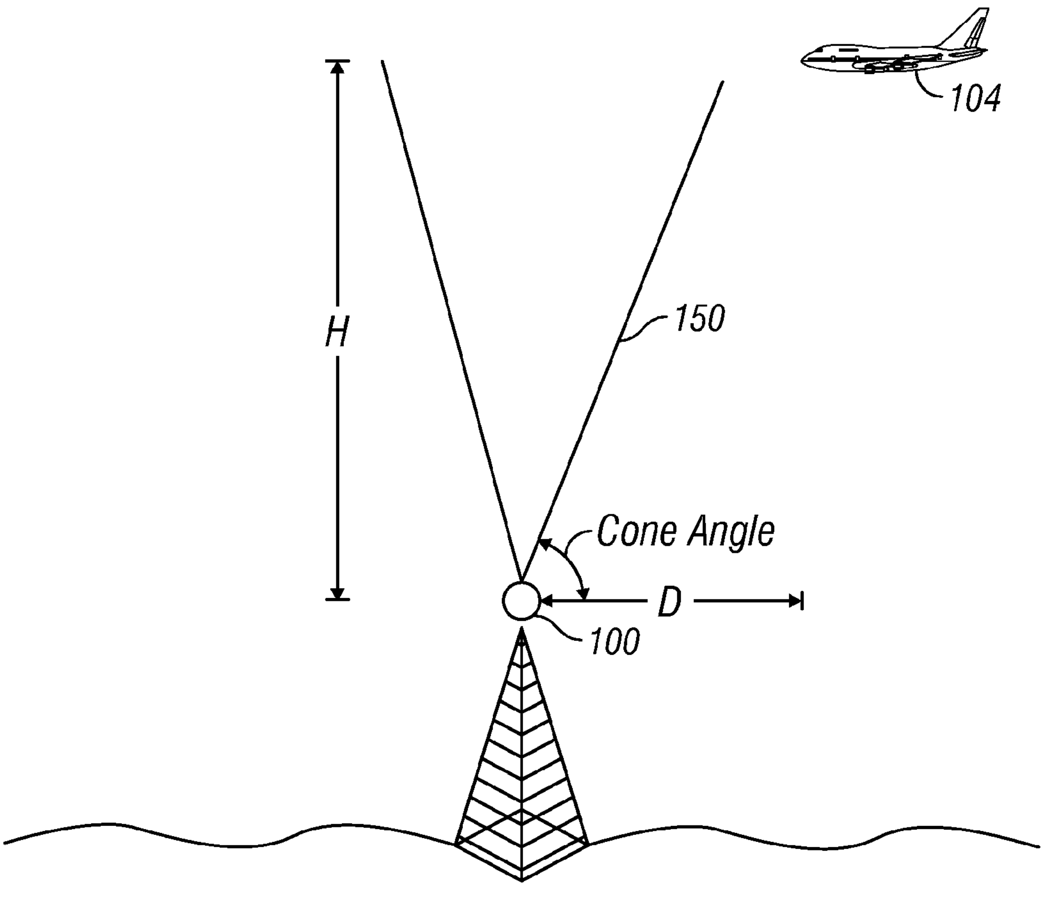

FIG. 3

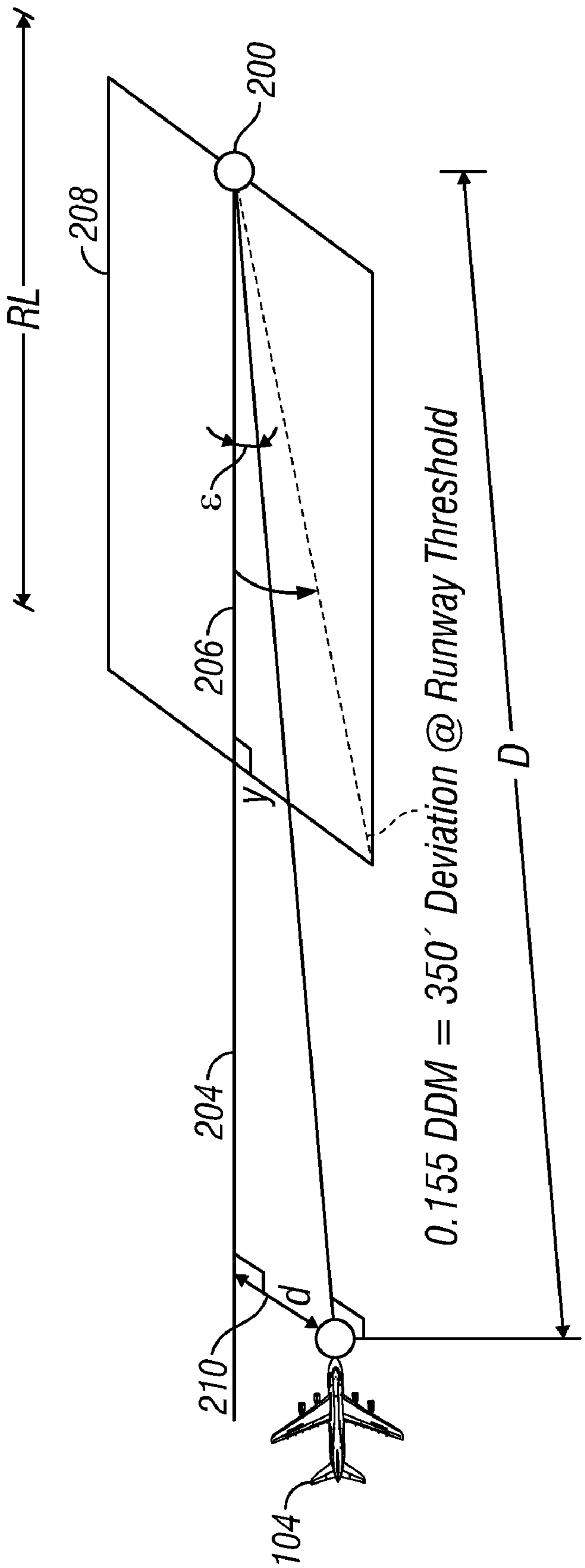
RL
200
208
ε
206
y
204
d
210
104
D
0.155 DDM = 350´ Deviation @ Runway Threshold

FIG. 4

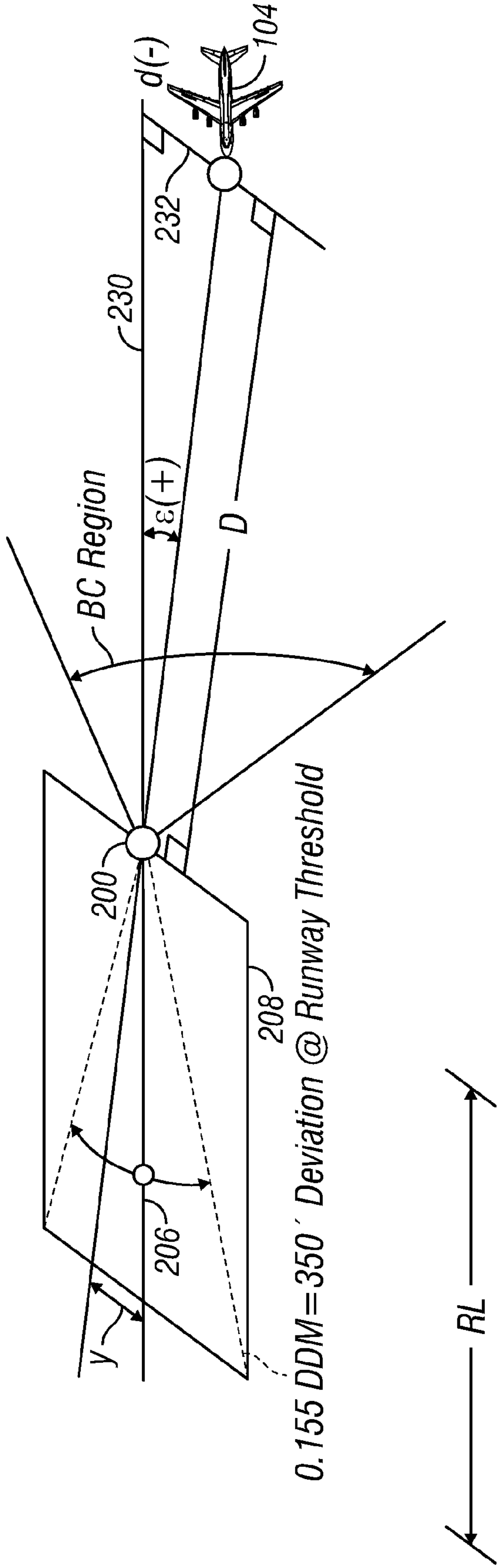
104
d(-)
232
230
BC Region
ε(+)
D
200
208
206
y
0.155 DDM=350´ Deviation @ Runway Threshold
RL

FIG. 5

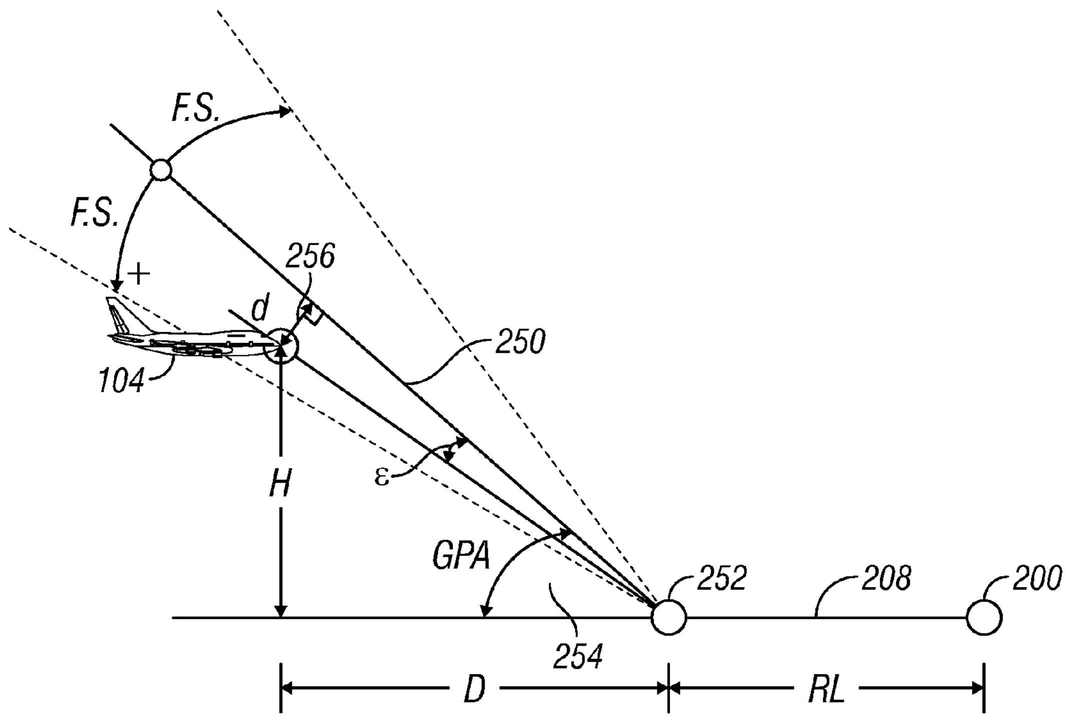

FIG. 6

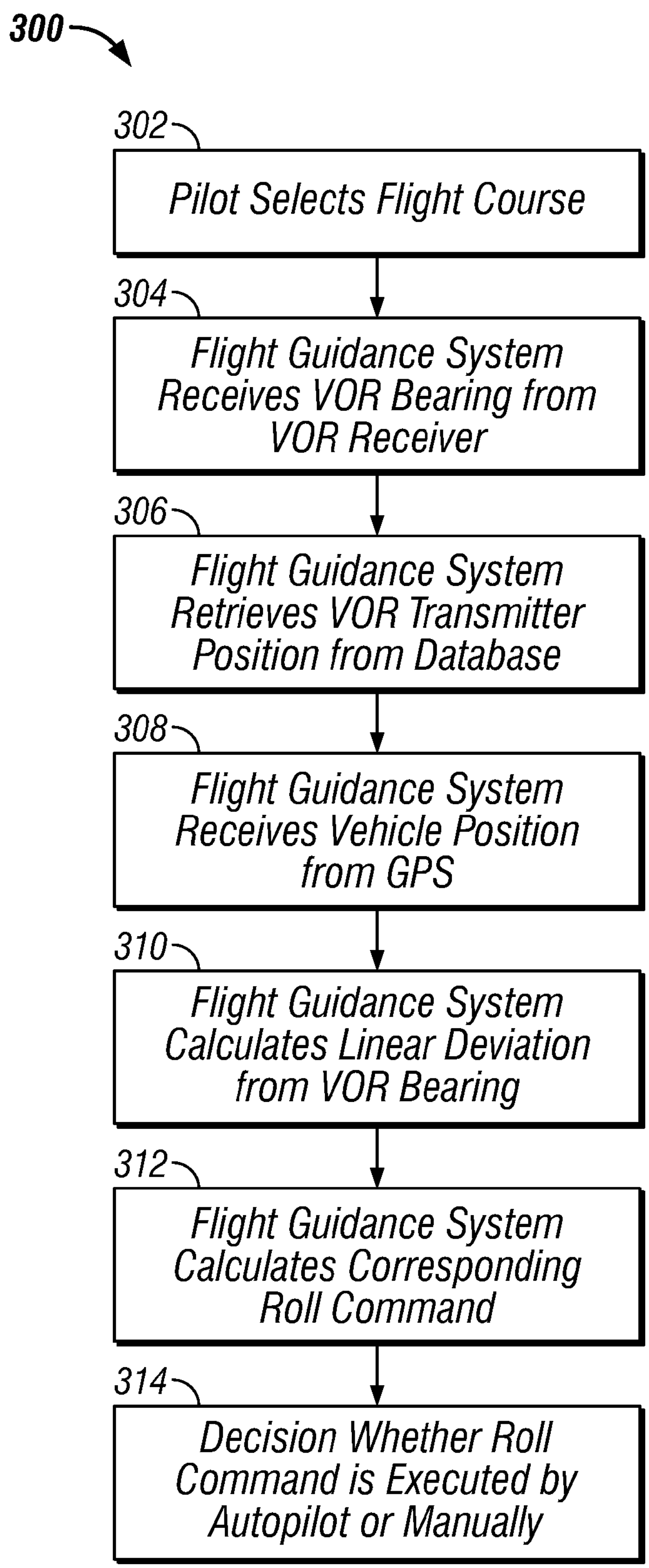
300
302
Pilot Selects Flight Course
304
Flight Guidance System Receives VOR Bearing from VOR Receiver
306
Flight Guidance System Retrieves VOR Transmitter Position from Database
308
Flight Guidance System Receives Vehicle Position from GPS
310
Flight Guidance System Calculates Linear Deviation from VOR Bearing
312
Flight Guidance System Calculates Corresponding Roll Command
314
Decision Whether Roll Command is Executed by Autopilot or Manually

FIG. 7

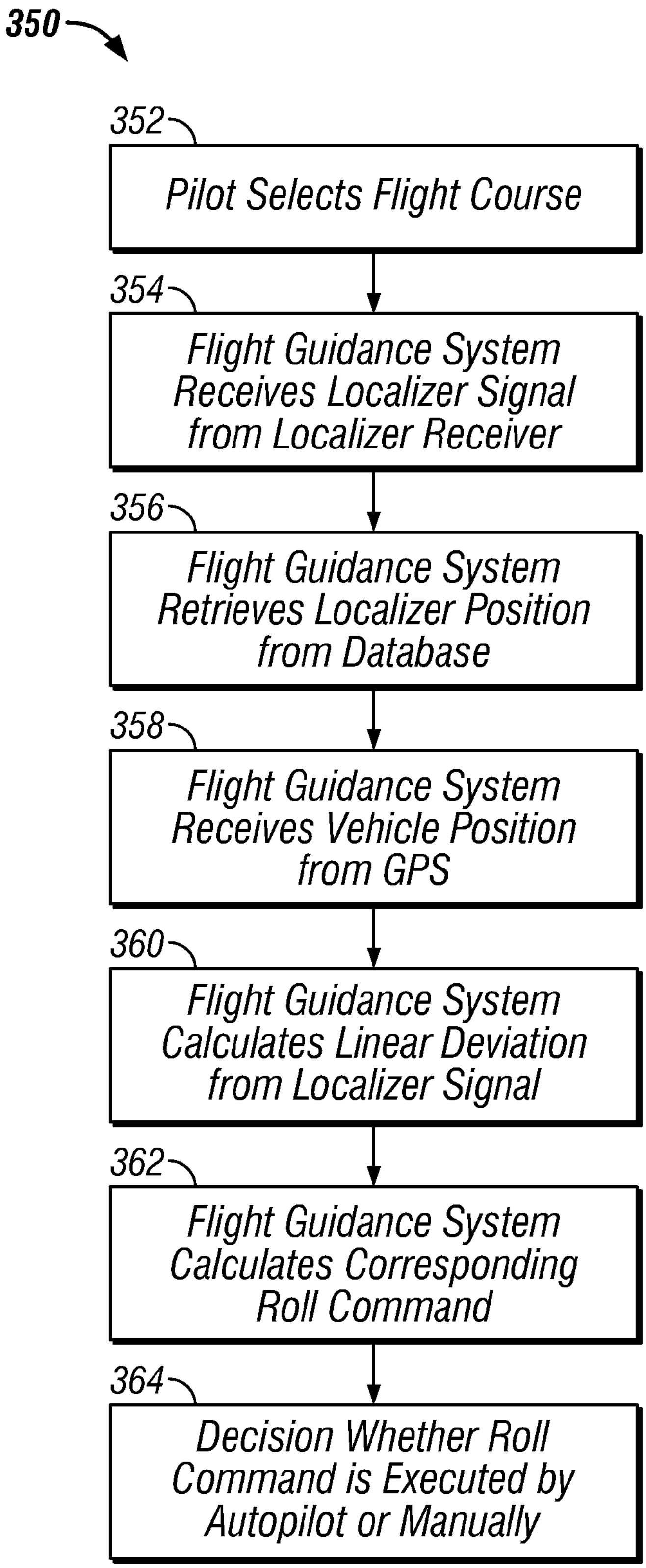
350
352
Pilot Selects Flight Course
354
Flight Guidance System Receives Localizer Signal from Localizer Receiver
356
Flight Guidance System Retrieves Localizer Position from Database
358
Flight Guidance System Receives Vehicle Position from GPS
360
Flight Guidance System Calculates Linear Deviation from Localizer Signal
362
Flight Guidance System Calculates Corresponding Roll Command
364
Decision Whether Roll Command is Executed by Autopilot or Manually

FIG. 8

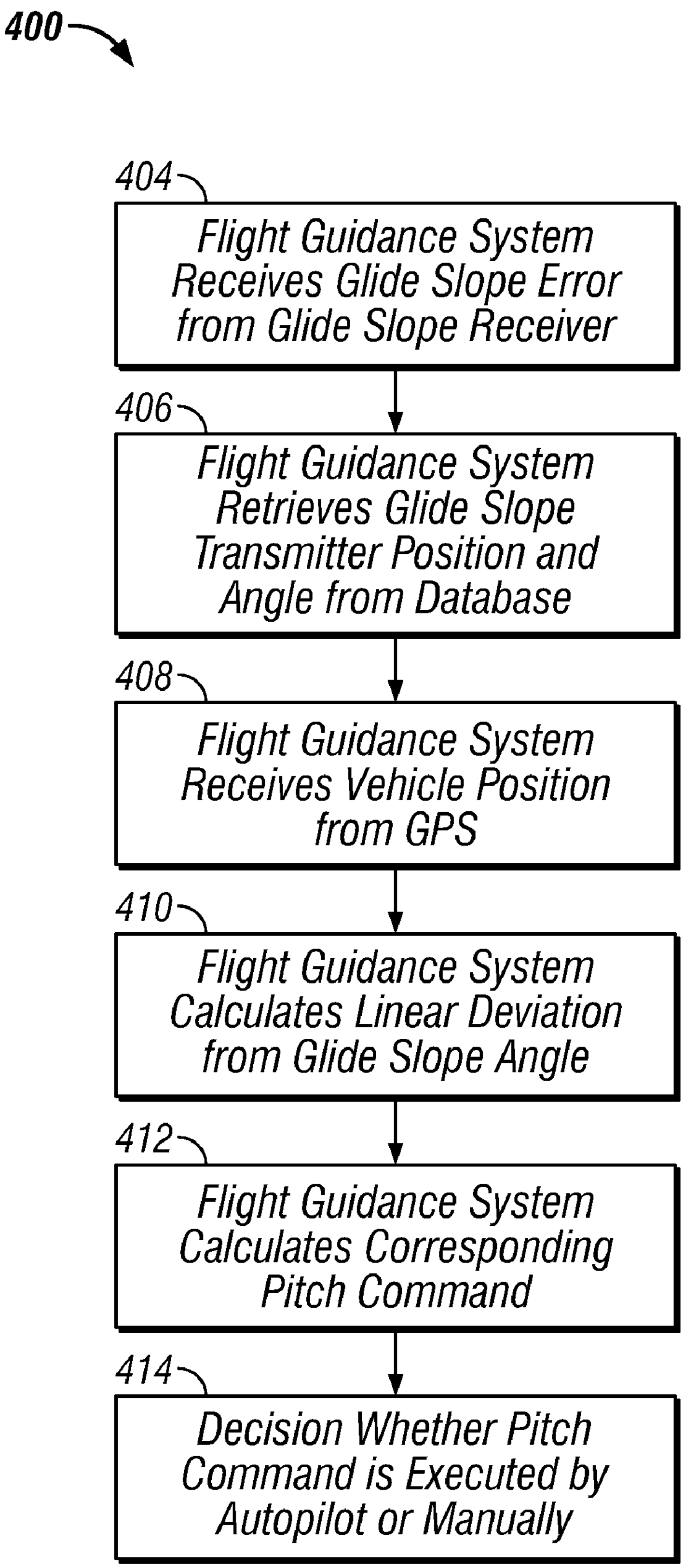
400
404
Flight Guidance System Receives Glide Slope Error from Glide Slope Receiver
406
Flight Guidance System Retrieves Glide Slope Transmitter Position and Angle from Database
408
Flight Guidance System Receives Vehicle Position from GPS
410
Flight Guidance System Calculates Linear Deviation from Glide Slope Angle
412
Flight Guidance System Calculates Corresponding Pitch Command
414
Decision Whether Pitch Command is Executed by Autopilot or Manually

FIG. 9

METHOD AND SYSTEM FOR USING A DATABASE AND GPS POSITION DATA TO GENERATE BEARING DATA

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is a divisional of U.S. patent application Ser. No. 10/818,900, filed Apr. 6, 2004, which in turn is a continuation-in-part of U.S. application Ser. No. 10/736,969, now U.S. Pat. No. 7,337,063, filed Dec. 16, 2003. The above-identified applications are hereby incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

The present invention relates generally to aircraft navigation and landing. More specifically, embodiments of the invention relate to methods and systems for navigating and landing aircraft.

A VHF (very high frequency) Omni-directional Range (VOR) navigation system is implemented by dispersing VOR transmitter facilities across a geographic area. VOR receivers are located on aircraft which navigate through such a geographic area. The basic principle of operation of the VOR navigation system includes transmission from the VOR transmitter facilities transmitting two signals at the same time. One VOR signal is transmitted constantly in all directions, while the other is rotatably transmitted about the VOR transmission facility. The airborne VOR receiver receives both signals, analyzes a phase difference between the two signals, and interprets the result as a radial to or from the VOR transmitter **100**. The VOR navigation system allows a pilot to simply, accurately, and without ambiguity navigate from VOR transmitter facility to VOR transmitter facility. Each VOR transmission facility operates at a frequency that is different from surrounding VOR transmitters. Therefore a pilot can tune their VOR receiver to the VOR transmission facility to which they wish to navigate. Widely introduced in the 1950s, VOR remains one of the primary navigation systems used in aircraft navigation.

The rotating transmission signal is achieved through use of a phased array antenna at the VOR transmission facility. Separation between elements of the array causes nulls in the signal received at the aircraft. Element separation may also cause erratic signal reception when an aircraft is within an area above the antenna array. Such nulls result in a conically shaped area originated at the VOR transmitter and extending upward and outward at a known angle. The conically shaped area is sometimes referred to as a cone of confusion. When an aircraft is within the cone of confusion, a pilot typically navigates utilizing only heading information, a process sometimes referred to as dead-reckoning. It is advantageous for a pilot to know that he or she is entering the cone of confusion.

An instrument landing system (ILS) also includes ground based transmitters, located at runways, and airborne receivers. The ILS transmitters transmit signals, received by the receivers on the aircraft, which are utilized to align an aircraft's approach to a runway. Typically, an ILS consists of two portions, a localizer portion and a glide slope portion. The localizer portion is utilized to provide lateral guidance and includes a localizer transmitter located at the far end of the runway. The glide slope portion provides vertical guidance to a runway and includes a glide slope transmitter located at the approach end of the runway. More specifically, a localizer signal provides azimuth, or lateral, deviation information which is utilized in guiding the aircraft to the centerline of the runway. The localizer signal is similar to a VOR signal except that it provides radial information for only a single course, the runway heading. The localizer signal includes two modulated signals, and a null between the two signals is along the centerline path to the runway.

The glide slope provides vertical guidance to the aircraft during the ILS approach. The glide slope includes two modulated signals, with a null between the two signals being oriented along the glide path angle to the runway. If the aircraft is properly aligned with the glide slope signal, the aircraft should land in a touchdown area of the runway. A standard glide slope or glide path angle is three degrees from horizontal, downhill, to the approach-end of the runway. Known flight guidance systems, sometimes referred to as flight control systems, are configured to assume a nominal glide path angle, for example, three degrees. Some known flight guidance systems have difficulty capturing the null in the glide slope signal at runways whose glide path angle varies significantly from the assumed glide path angle.

The VOR, localizer, and glide slope all provide an angular deviation from a desired flight path. The angular deviation is the angle between the current flight path and the desired flight path. Depending on a distance from a transmitter, a linear change to the flight path to correct an angular deviation can vary widely. A linear deviation is the current distance between the current flight path and the desired flight path. Furthermore, most flight guidance systems are better suited to receive and process linear deviations from a desired flight path. Known flight guidance systems utilize data from distance measuring equipment (DME) and radar altimeters to convert angular deviations in one or more of VOR, localizer, and glide slope, into linear deviations that can be acted upon by a pilot or a flight guidance system. Therefore, aircraft not equipped with DME or a radar altimeter are not able to convert the angular deviations into linear deviations that can be optimally acted upon by the flight guidance system.

Known flight guidance systems utilize distance information from DME to estimate a distance to a VOR transmitter. The estimated distance, along with an angular deviation as determined from the VOR bearing is utilized to determine a linear deviation from a desired flight path and detect a cone of confusion. However, this approach assumes a default VOR transmitter station elevation, that the aircraft is equipped with DME, and that a DME station is co-located with the VOR transmitter.

Known flight guidance systems also utilize altitude information from, for example, a radar altimeter to estimate localizer deviations. The altitude, along with an angular deviation as determined by the localizer receiver is utilized along with an assumption of runway length to determine a localizer linear deviation from a desired flight path. For glide slope linear deviations, the altitude, an angular deviation as determined by a glide slope receiver, and an assumed glide path angle are utilized to estimate the linear deviation from a desired glide slope. These estimations assume that the aircraft is equipped with an altitude measuring device (e.g. radar altimeter). It would be advantageous to utilize actual data relating to VOR, localizers, glide slopes, and runway lengths and altitudes when providing a pilot or an auto pilot system navigation data. Similarly, it would be advantageous to provide such navigation data in aircraft which are not equipped with radar altimeters or DME.

In addition, known flight guidance systems are not able to properly capture the localizer signals under conditions of high ground speeds and high intercept angles, due to the limited beamwidth of the transmitter and saturation of the localizer receiver at the necessary aircraft positions. This results in late captures and potentially significant overshoot in acquiring the proper course.

Further, known flight guidance systems also do not track the selected VOR course while traversing the "cone of confusion", depending on maintaining the aircraft heading at the time the cone of confusion is entered. This may result in significant tracking errors when the VOR signal is re-acquired upon exiting the cone, especially if wind changes or selected course occur during passage of the VOR station.

BRIEF DESCRIPTION OF THE INVENTION

In one embodiment of the present invention, a method for providing a bearing from a vehicle to a transmitting station is provided. The method comprises accessing a database to obtain transmitter position information for the transmitter, obtaining vehicle position information based on a GPS signal, and generating the bearing from the vehicle to the station utilizing the transmitter position information and the vehicle position information.

In another embodiment of the present invention, a system for providing a bearing signifying a deviation of a vehicle from a desired course is provided. The system comprises a database storing transmitter position information identifying a position of a transmitter transmitting bearing signals to the vehicle, a GPS receiver obtaining vehicle position information identifying a current position of the vehicle based on a GPS signal, and a controller generating a bearing from the vehicle to the transmitter utilizing the transmitter position information and the vehicle position information.

In still another embodiment of the present invention, a computer program product embodied on a computer readable medium for determining a bearing from a vehicle to a transmitter is provided. The computer program product comprises a data reception source code segment receiving data relating to a position of the vehicle as determined from one or more positioning sensors and a database access source code segment retrieving data from a database relating to a position of the transmitter. The computer program product also comprises a determination source code segment determining a bearing from the vehicle to the transmitter utilizing the data relating to vehicle position and the data relating to transmitter position.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and features of the invention noted above are explained in more detail with reference to the drawings which form a part of the specification and which are to be read in conjunction therewith, and in which like reference numerals denote like elements in the various views.

FIG. **1** is a block diagram of a portion of a flight guidance system according to one embodiment of the present invention.

FIG. **2** is a diagram illustrating a number of parameters utilized in calculating a linear deviation from a desired path to a VOR transmitter.

FIG. **3** is a diagram illustrating a number of parameters utilized in estimating a cone of confusion above a VOR transmitter.

FIG. **4** is a diagram illustrating a number of parameters utilized in calculating a linear deviation from a desired path to a localizer transmitter.

FIG. **5** is a diagram illustrating a number of parameters utilized in calculating a linear deviation from a desired back course path to a localizer transmitter.

FIG. **6** is a diagram illustrating a number of parameters utilized in calculating a linear deviation from a desired path to a glide slope transmitter.

FIG. **7** is a flowchart describing a method for determining a linear deviation from a desired path to a VOR transmitter.

FIG. **8** is a flowchart describing a method for determining a linear deviation from a desired path to a localizer transmitter.

FIG. **9** is a flowchart describing a method for determining a linear deviation from a desired glide slope angle.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a block diagram of a portion of a flight guidance system **10** according to one embodiment of the present invention. The flight guidance system **10**, typically including a flight director and autopilot function, includes a microprocessor **12** that is coupled to each of a program memory **14**, a database **16**, pilot controls **18**, and a pilot display **20**. In the embodiment shown, the flight guidance system **10** receives aircraft position data from GPS receiver **30**, which is connected to GPS antenna **32**. The flight guidance system **10** also receives inputs from a VHF Omni-directional Range (VOR) receiver **40**, which is connected to VOR antenna **42**. As described above, the VOR system is utilized to navigate from VOR transmitter to VOR transmitter along a planned flight path. VOR transmitters are interspersed across a geographic area to provide navigation references for aircraft equipped with VOR receivers **40**.

Once an aircraft has navigated past the last VOR transmitter in the planned flight path, it will begin an approach to an airport, and may begin to receive signals from an instrument landing system (ILS). As the air vehicle (not shown in FIG. **1**) in which the flight guidance system **10** is installed approaches the runway for landing, it will receive input data from the ILS. An ILS may include a localizer receiver **50**, localizer antenna **52**, a glide slope receiver **60**, and a glide slope antenna **62**. The flight guidance system **10** also receives altitude data **70** from an altitude source, for example, an altimeter corrected for barometric pressure (not shown).

The localizer receiver **50**, and the glide slope receiver **60** receive signals from corresponding transmitters (not shown in FIG. **1**). A localizer transmitter is located at a far end of a runway and a glide slope transmitter is located at an approach end of the runway. The localizer and glide slope transmitters and receivers (**50**,**60**) aid a pilot in properly aligning an aircraft with the runway for landing. The localizer is utilized for a lateral alignment, and the glide slope for maintaining a proper vertical approach angle to the runway.

The database **16** may include location information (i.e. latitude, longitude, and elevation) for each respective VOR transmitter, localizer transmitter, and glide slope transmitter. In addition, runway lengths and glide path angles are maintained in database **16** for various runways. In one embodiment, data within database **16** relating to VOR transmitter latitude and longitude are utilized along with aircraft position (latitude and longitude from GPS receiver) to determine a horizontal distance and bearing to the transmitter. As utilized herein, a horizontal distance is the distance along the ground between two points. The horizontal distance from the transmitter is utilized along with an angular deviation from a desired flight path, for example from VOR receiver **40**, to determine a linear deviation from a desired flight path. Utilizing the linear deviation, the flight guidance system **10** determines, for example, pitch and roll commands to steer the vehicle to the desired flight path.

In the case of VOR, the height above the VOR transmitter, sometimes referred to as a VOR station, is also utilized to determine a cone of confusion for the VOR station, as further described below. Data relating to runway length for individual runways is stored in database **16** which is utilized, along with an angular deviation from the desired flight path provided by localizer receiver **50**, to determine a linear deviation from a desired lateral approach to a runway. Data relating to glide path angles for individual runways is also stored in database **16**. Such data, along with an angular deviation from the desired glide path angle provided by glide slope receiver **60**, is utilized in determining a linear deviation from the desired glide path angle to a runway.

FIG. **2** is a diagram illustrating the parameters utilized in calculating a linear deviation, d, from the desired flight path **102**. VOR transmitter **100** operates to provide a direction to the transmitter **106**, sometimes referred to as VOR bearing, for an air vehicle **104**. The microprocessor **12** (shown in FIG. **1**) determines the difference between the desired course **102** and the current VOR bearing **106** as an angular deviation **108**, denoted as ϵ. While a pilot would want to change their flight path to that of the desired course **102**, an angular deviation does not provide much guidance. For example, if air vehicle **104** is 100 miles from the VOR transmitter **100**, an angular deviation of three degrees results in a linear deviation **110** in excess of five miles from the desired flight path **102**. However, if air vehicle **104** is only five miles from the VOR transmitter **100**, an angular deviation of three degrees results in a linear deviation of about 0.26 miles from the desired flight path **102**. From this simple example it is seen that a linear deviation is most useful in correcting a flight path of an air vehicle **104**.

In one embodiment, for VOR operation, the flight guidance system **10** (shown in FIG. **1**) uses the VOR transmitter **100** location data stored in the database **16** along with the current air vehicle position from GPS receiver **30** to determine a horizontal distance, D, and bearing **106** to the VOR transmitter **100**. This distance is used along with the angular deviation **108**, ϵ, which is the angular difference between **106** and **102**, to determine a linearized deviation **110** from the desired flight path **102**. The determination of the linear deviation **110** results in improved flight director and auto pilot tracking. For example, a bank (or turn) angle needed to reduce or eliminate the linear deviation **110** is displayed on pilot display **20** (shown in FIG. **1**).

Therefore, to linearize the signal from VOR receiver **40**, all that is needed is the horizontal distance to the VOR transmitter **100** and the angular deviation **108**, ϵ, provided by VOR receiver **40**. Using data relating to the VOR transmitter latitude and longitude from database **16** along with the GPS data for present latitude and longitude provides the horizontal distance, D. The resultant linearized deviation is calculated according to: VOR linear deviation=$d=D\times\sin(\epsilon)$. Utilizing the linear deviation, d, the flight guidance system **10** determines roll commands to steer the vehicle to the desired path **102**.

Flight guidance system **10** also utilizes an elevation of VOR transmitter **100** from database **16** and barometric altitude data to determine a height of air vehicle **104** above the VOR transmitter **100**. With such data and the horizontal distance D, flight guidance system **10** is able to determine a consistent "cone of confusion" extending above the VOR transmitter. As is further described below, the flight guidance system **10** will use dead reckoning to navigate the air vehicle through the cone of confusion, since the transmitter antenna pattern of VOR transmitter **100** will preclude stable signals being received by VOR receiver **40** (shown in FIG. **1**) in this region.

FIG. **3** illustrates a cone of confusion **150** created by an antenna array pattern at VOR transmitter **100**. To estimate a boundary for the cone of confusion **150**, a height, H, above the VOR transmitter **100** is required. This height is found by utilization of the elevation data for VOR transmitter **100** from database **16** and the present aircraft baro-corrected altitude from an air data system (e.g. altitude data **70**). The difference between the two is the height, H. The cone of confusion is then defined by the ratio of height, H above the station to the distance to the station, D, as defined above. Determination of whether air vehicle **104** is within the cone of confusion **150**, and therefore signals originating from VOR transmitter **100** are no longer useful, is a logical expression. If $H>D\times\tan$ (Cone Angle), where Cone Angle is nominally 60 degrees, then air vehicle **104** is in the cone of confusion **150**, and a pilot should utilize dead-reckoning to navigate through the cone, essentially acting as if the linear deviation, d, is zero.

As described above, during VOR transmitter **100** passage (e.g., air vehicle **104** is within the cone of confusion **150**) the signals transmitted from VOR transmitter **100** are unusable. In an alternative embodiment, instead of dead reckoning to navigate through the cone of confusion **150** only using heading information, a better track through the cone of confusion **150** is provided if a substituted deviation from GPS is generated for the deviation signals received from the VOR transmitter **100** during this time.

As also described above, flight guidance system **10** calculates a distance and bearing to the VOR transmitter **100** using the database values for the transmitter position of the VOR transmitter **100** and the GPS position of air vehicle **104**. In a specific embodiment, a bearing to the VOR transmitter **100** is calculated as $\arctan(x/y)$, if $y\geqq x$, and calculated as $(90-\arctan(y/x))$, if $x>y$ (to avoid dividing by zero), where x is the longitudinal difference (i.e. distance in East-West direction) between air vehicle **104** and VOR transmitter **100** and y is the latitude difference (i.e. distance in North-South direction) between the two.

Therefore, the generated bearing data from air vehicle **104** to VOR transmitter **100** is substituted for the deviation based on the transmitted VOR deviation signals when the signals are insufficient for reception at air vehicle **104**, for example, due to a geometry of the transmitted VOR deviation signal.

FIG. **4** illustrates operation of the localizer portion of the ILS for linearization of an angular deviation from a desired path, according to another embodiment of the present invention. As described above, a localizer transmitter **200** transmits localizer signals which are received by localizer receiver **50** which then determines an azimuth, or angular lateral deviation from a desired path **204** to guide the air vehicle **104** to the centerline **206** of runway **208**. As is shown in FIG. **4**, localizer transmitter **200** is located at an end of runway **208** that is opposite an approaching air vehicle **104**.

To determine a linear deviation from desired path **204** utilizing the localizer signal, the flight guidance system **10** utilizes the data relating to location for the localizer transmitter **200** from the database **16** along with the current position of air vehicle **104** as determined through GPS receiver **30** to determine a horizontal distance, D, to the localizer transmitter **200**. This distance, D is utilized along with a runway length, RL, from the database **16**, and the angular deviation, ϵ, as determined by the localizer system (transmitter **200**, localizer receiver **50**) into a linear deviation **210**, d, with a constant scale factor to improve auto pilot tracking and performance of the flight guidance system **10**.

Specifically, to linearize the deviation from the localizer portion of the ILS, an end of runway deviation, y, is first determined through normalization of the localizer angular deviation by accounting for the constant beam width of 350 feet full scale at the threshold (approach end) of all runways. A full scale value (350 feet from a centerline of the runway **208** at the end of the runway opposite the localizer transmitter **200**) for localizer angular deviation is represented as 0.155 DDM (difference in depth of modulation) at an output of the localizer receiver **50**. A difference in depth of modulation occurs because the localizer transmitter **200** transmits two modulated signals.

Therefore, an end of runway deviation is calculated as

$$y = \frac{\varepsilon}{0.155DDM} \times 350 \text{ feet} = 2258\varepsilon(\text{ft}) = 688.258\varepsilon(m).$$

To then determine a linear deviation, d, at the air vehicle **104** from the desired path **204**, the distance D, to localizer transmitter, and the database value for the length of the runway, RL, along with the end of runway deviation, y, is are utilized according to

$$d = \frac{D \times y}{\sqrt{RL^2 + y^2}}.$$

Such an approach by an air vehicle **104** is sometimes referred to as an ILS front course approach.

Sometimes, perhaps due to wind conditions, an aircraft **104** must approach the runway **208** in a direction that is opposite to the approach direction intended when the localizer transmitter **200** was installed. Such an approach is sometimes referred to as a back course approach. Determination of a linear deviation from a desired back course approach is illustrated in FIG. **5**. During a back course approach, the localizer transmitter **200** is located at the approach end of the runway **208**. As above, the localizer transmitter **200** transmits localizer signals which are received by localizer receiver **50** which then determines an azimuth, or angular lateral deviation from a desired path **230** to guide the air vehicle **104** to the centerline **206** of runway **208**, albeit from the opposite direction. The linearization equations are the same for back course approach as the ILS front course approach described above except for a change in sign.

Therefore, an end of runway deviation is calculated as

$$y = \frac{\varepsilon}{0.155DDM} \times 350 \text{ feet} = 2258\varepsilon(\text{ft}) = 688.258\varepsilon(m).$$

To then determine a linear deviation **232**, d, at the air vehicle **104** from the desired path **230**, the distance D, to the localizer transmitter, and the database value for the length of the runway, RL, along with the end of runway deviation, y, are utilized according to

$$d = -\frac{D \times y}{\sqrt{RL^2 + y^2}}.$$

Similar to passage of VOR transmitter **100** through the cone of confusion **150** described above, the signal from the localizer transmitter **200** sometimes cannot be used by air vehicle **104**. One such example is when the air vehicle **104** is far enough away from the desired path **204** that the output of localizer receiver **50** reaches a maximum value (also known as saturation). In such a case, a capture cannot be calculated by localizer receiver **50** because there is no sense of deviation rate from the transmitted localizer signal. This causes the flight guidance system to wait until the receiver output is no longer saturated before starting a turn to acquire the localizer signal. This may be too late for the limited bank angles utilized by the flight guidance system. Such late capture of the localizer signal can sometimes result in an overshoot of the desired path **204** by air vehicle **104**. Sometimes the overshoot by air vehicle **104** is significant and a resultant position of air vehicle **104** is quite a distance from the desired path **204**.

In an alternative embodiment, flight guidance system **10** is configured to cause a capture of the transmitted localizer signal when the transmitted localizer signal from the localizer transmitter **200** cannot be captured by localizer receiver **50**, based on a derived deviation from desired path **204**. Utilizing the derived deviation from desired path **204**, air vehicle **104** is able to begin turning at a location (referred to herein as a capture point) which will allow the localizer signal to be acquired without significantly overshooting the desired path **204**.

Similar to the calculation of a derived bearing to VOR transmitter **100** described above, flight guidance system **10** determines a distance and bearing to the localizer transmitter **200** using the database values for the transmitter position of the localizer transmitter **200** and the GPS position of air vehicle **104**. This bearing and distance information is used to calculate a substitute deviation from the desired path **204**, which provides the information necessary to capture and acquire the localizer while the receiver is in saturation. In a specific embodiment, a bearing to the localizer transmitter **200** is calculated as arctan(x/y), if $y \geqq x$, and calculated as (90−arctan(y/x)), if $x>y$ (to avoid dividing by zero), where x is the longitudinal difference between air vehicle **104** and localizer transmitter **200** and y is the latitude difference between the two.

Therefore, the bearing data from air vehicle **104** to the desired path **204** to localizer transmitter **200** is utilized in conjunction with the distance data between the two to calculate a deviation that substitutes for the transmitted localizer deviation signal when the signal is saturated, which means that the signal is insufficient for reception at air vehicle **104**. The calculated deviation signal augments the transmitted localizer signals and allows capture of the transmitted localizer signals under situations, for example high speeds and intercept angles, when a capture based on the transmitted localizer signals occurs too late to avoid an overshoot.

FIG. **6** illustrates operation of the glide slope portion of the ILS. Specifically, to determine a linear deviation from the glide slope path **250**, the flight guidance system **10** uses data relating to a location for the glide slope transmitter **252** from the database **16** along with the current aircraft position from GPS receiver **30** to determine a horizontal distance, D, to the glide slope transmitter **252**. This horizontal distance, D, is used along with the glide path angle **254** from the database **16** to convert an angular altitude deviation signal received from glide slope receiver **60** into a linearized deviation, d, **256** with a constant scale factor to improve autopilot tracking and operation of flight guidance system **10**.

To linearize the angular error from the glide path angle utilizing the glide slope portion of the ILS, the distance, D, to the glide slope transmitter **252** is used. The distance, D, is determined as the difference between air vehicle position, provided by GPS receiver **30** and data relating to the location of the glide slope transmitter **252** from database **16**. In one embodiment, the database **16** does not include data relating to a position of the glide slope transmitter **252**. Rather, in such an embodiment, data relating to a position of the localizer transmitter **200** along with data relating to runway length are utilized to estimate a position of the glide slope transmitter **252**.

The glide path angle, GPA, stored in database **16**, and height above the station, H, which is derived from the transmitter **252** elevation in database **16**, and elevation of air vehicle **104** (from either a GPS or an air data computer **70** (shown in FIG. **1**)) are utilized to determine if an unwanted side lobe of the glide slope signal is being received, as opposed to the desired main beam. This determination of main/side lobe helps to prevent false captures.

FIG. **6** shows the geometry of the linearization, where ϵ is the GS deviation error in DDM, and the full scale (F.S.) value for glide slope deviation is represented as 0.175DDM at the glide slope receiver **60** output, corresponding to 0.2×GPA from the database **16**. The glide slope deviation error angle in radians is

$$\alpha = \frac{\varepsilon}{0.175DDM} \times 0.2GPA,$$

and the glide slope linear deviation is

$$d = \frac{D}{\cos(GPA - \alpha)} \times \sin(\alpha).$$

If (0.75×GPA)<arctan(H/D)<(1.5×GPA), then capture is allowed.

The above described calculation of deviation signals that substitute for the transmitted localizer deviation signal and calculation of a capture point for the transmitted localizer signals along a desired path are also applicable to capture of glide slope transmitter transmissions using the same methodology.

FIG. **7** is a flowchart **300** illustrating the methods disclosed herein for linearizing a deviation from a VOR bearing signal. Referring to flowchart **300**, a pilot selects **302** a flight course. Flight guidance system **10** (shown in FIG. **1**) receives **304** a VOR bearing from the VOR receiver **40** (shown in FIG. **1**). The flight guidance system **10** retrieves **306** a position (i.e. latitude, longitude, and elevation) of the VOR transmitter **100** (shown in FIG. **2**). The flight guidance system **10** then receives **308** a vehicle position (i.e. latitude, longitude, and elevation) from a GPS receiver **30** (shown in FIG. **1**). The flight guidance system **10** calculates **310** a linear deviation from the VOR bearing utilizing the methodology described with respect to FIG. **2**. Upon calculation **310** of the linear deviation, the flight guidance system **10** is configured to calculate **312** a roll command that corresponds to a roll that is needed to minimize the deviation from the VOR bearing signal. The pilot then decides **314** whether the roll command is to be executed manually or through an auto pilot system.

FIG. **8** is a flowchart **350** illustrating the methods disclosed herein for linearizing a deviation from a center of a localizer signal that is a portion of the functionality provided by an ILS. The method is similar to that associated with determining a linear deviation from a VOR bearing (shown in FIG. **7**). Referring to flowchart **350**, a pilot selects **352** a flight course. Flight guidance system **10** (shown in FIG. **1**) receives **354** localizer data from the localizer receiver **50** (shown in FIG. **1**). The localizer data is in the form of a deviation from a null between the localizer's transmitted beams. The flight guidance system **10** retrieves **356** a position (i.e. latitude, longitude, elevation, and runway length) of the runway associated with the localizer transmitter **200** (shown in FIG. **4**). The flight guidance system **10** then receives **358** a vehicle position (i.e. latitude, longitude, and elevation) from a GPS receiver **30** (shown in FIG. **1**). The flight guidance system **10** calculates **360** a linear deviation from the localizer signal utilizing the methodology described with respect to FIG. **4**. Upon calculation **360** of the linear deviation, the flight guidance system **10** is configured to calculate **362** a roll command that corresponds to a roll that is needed to minimize the deviation from the localizer signal. The pilot then decides **364** whether the roll command is to be executed manually or through an auto pilot system. A method similar to that illustrated by flowchart **350** is utilized in determining a linear deviation from a desired path for a back course approach to a runway.

FIG. **9** is a flowchart **400** illustrating the methods disclosed herein for linearizing an angular altitude deviation from the ILS glide path. The glide slope angular altitude deviation is a portion of the functionality provided by an ILS. The method is similar to that associated with determining a linear deviation from a VOR bearing (shown in FIG. **7**). Referring to flowchart **400**, flight guidance system **10** (shown in FIG. **1**) receives **404** a glide slope error angle from the glide slope receiver **60** (shown in FIG. **1**). The flight guidance system **10** retrieves **406** a position (i.e. latitude, longitude, elevation) and a glide path angle that is defined for the runway associated with glide slope transmitter **252** (shown in FIG. **6**). The flight guidance system **10** then receives **408** a vehicle position (i.e. latitude, longitude, and elevation) from a GPS receiver **30** (shown in FIG. **1**). The flight guidance system **10** calculates **410** a linear deviation from the glide path angle utilizing the methodology described with respect to FIG. **6**. Upon calculation **410** of the linear deviation, the flight guidance system **10** calculates **412** a pitch command that is needed to reduce the deviation from the glide path angle. The pilot then decides **414** whether the pitch command is to be executed manually or through an auto pilot system.

The described systems and methods are able to achieve improved performance over classical methods, due to the use of GPS position data and database values for transmitter positions.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A method for providing a bearing from a vehicle to a transmitting station, said method comprising:
  - accessing a database to obtain transmitter position information for the transmitting station;
  - obtaining vehicle position information based on a GPS signal;
  - generating the bearing from the vehicle to the transmitting station utilizing the transmitter position information and the vehicle position information;
  - identifying when the vehicle is in a VOR cone of confusion extending from the transmitting station based on the transmitter position information and the vehicle position information; and
  - calculating an estimated deviation representing a deviation from a desired course to the transmitting station using the bearing from the vehicle to the transmitting station.

2. The method according to claim 1, wherein the accessing obtains transmitter position information for the location of at least one of a VOR transmitter, a localizer transmitter of an instrument landing system (ILS), and a glide slope transmitter of the ILS.

3. The method according to claim 1, further comprising:
determining a distance to the transmitting station; and
calculating a deviation representing a deviation from a desired course to the transmitting station using the distance and the bearing from the vehicle to the transmitting station.

4. The method according to claim 1, further comprising:
determining a distance to the transmitting station;
calculating a deviation representing a deviation from a desired course to the transmitting station using the distance and the bearing from the vehicle to the transmitting station; and
utilizing the calculated deviation in connection with control of the vehicle when the signals from the transmitting station are of insufficient strength to be captured by a signal receiver.

5. The method according to claim 1, wherein generating the bearing comprises:
determining vehicle latitude and longitude from the vehicle position information and transmitting station latitude and longitude from the vehicle position information; and
calculating a bearing to the transmitting station from the differences between the vehicle and transmitting station latitudes and longitudes.

6. The method according to claim 1, further comprising calculating a flight director roll command utilizing the bearing from the vehicle to the transmitting station.

7. The method according to claim 1, further comprising initiating a flight director roll command to an auto-pilot function utilizing the bearing from the vehicle to the transmitting station.

8. The method according to claim 1, wherein the transmitting station is a localizer transmitter, and wherein generating the bearing comprises:
calculating a deviation from a desired path to the localizer transmitter using the vehicle position information; and
using the deviation to calculate a bearing to a capture point for the signals transmitted from the localizer transmitter.

9. The method according to claim 1, wherein the transmitting station is a glide slope transmitter, and wherein generating the bearing comprises:
calculating a deviation from a desired path to the glide slope transmitter using the vehicle position information; and
using the deviation to calculate a bearing to a capture point for the signals transmitted from the glide slope transmitter.

10. A method for providing a bearing from a vehicle to a transmitting station, said method comprising:
accessing a database to obtain transmitter position information for the transmitting station;
obtaining vehicle position information based on a GPS signal;
calculating a deviation from a desired path to the transmitting station using the vehicle position information and the transmitter position information; and
using the deviation to calculate a bearing to a capture point for the signals transmitted from the transmitting station.

11. The method of claim 10, wherein the transmitting station is at least one of a localizer transmitter and a glide slope transmitter and the accessing includes accessing a database including transmitter position information for a plurality of localizer transmitters and glide slope transmitters.

12. The method according to claim 10, further comprising:
determining a distance to the transmitting station; and
calculating a deviation representing a deviation from a desired course to the transmitting station using the distance and the bearing from the vehicle to the transmitting station.

13. The method according to claim 10, further comprising:
determining a distance to the transmitting station;
calculating a deviation representing a deviation from a desired course to the transmitting station using the distance and the bearing from the vehicle to the transmitting station; and
utilizing the calculated deviation in connection with control of the vehicle when the signals from the transmitting station are of insufficient strength to be captured by a signal receiver.

14. The method according to claim 10, further comprising calculating a flight director roll command utilizing the bearing from the vehicle to the transmitting station.

15. The method according to claim 10, further comprising initiating a flight director roll command to an auto-pilot function utilizing the bearing from the vehicle to the transmitting station.

16. The method according to claim 10, wherein said generating partitions processing among multiple processors to generate the bearing and a resulting flight director command.

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