

TITLE OF THE INVENTION

AUTONOMOUS RADIO FREQUENCY MAPPING

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BACKGROUND OF THE INVENTION

(a) Field of Invention

10 The present invention relates to radio frequency (RF) mapping.

(b) Brief Description of the Prior Art

15 RF signals relating to sensed parameters or measurements are transmitted from an object, such as an aircraft or vehicle, to receiving or tracking stations. However, after the installation of an antenna on a large scale vehicle, the radiation pattern of the transmitting antenna will be altered due to the interaction of the antenna with the vehicle's structure. The altered radiation
20 pattern needs to be mapped to understand the coverage (e.g. signal strength) of the transmission antenna as a function of azimuth and elevation relative to the vehicle. Also, it may be that the location of the antenna is less than optimal, in that inference effects due to the vehicle's structure occur.

25 A known method to do that is to map the radiation pattern by manually moving a receiving antenna around the vehicle while the transmitting antenna is operational. The current practice for RF mapping is labour intensive and is prone to human error. For instance, if a measurement needs to be repeated, then the path to be followed may not be accurately reproduced.

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Accordingly, it is an object of the present invention to provide an autonomous RF mapping vehicle which can overcome or at least reduce the above mentioned drawbacks.

SUMMARY

According to one aspect, there is provided an autonomous vehicle operable to traverse a scanning path around a test object having a radio frequency signal source, said vehicle comprising a height controllable antenna mounted onto the autonomous vehicle; a Central Processing Unit (CPU) providing control of the autonomous vehicle; a navigation system for calculating relative distance and direction for the autonomous vehicle's scanning path around the test object; a vehicle control system responsive to said CPU for positioning the vehicle at an initial scanning position and for causing traversal of the scanning path; an antenna elevation system being controlled by the CPU to set the antenna to one or more heights during the scanning path; and a data acquisition system for acquiring and storing at least RF signal strength continuously in the course of said scanning path; and a user input means for a user to input a reference location for said test object, said scanning path and said one or more heights, and said navigation system has a positioning system and calculates said relative distance from said reference location and the location of the vehicle.

According to an alternative aspect, there is provided a method for mapping the radiation pattern of transmitting antenna carried by an object, comprising the steps of :

- (a) an autonomous vehicle locating itself positionally;
- (b) the vehicle determining the location of the object and determining a start point of scanning path with reference to the object; and
- (c) the vehicle traversing the scanning path and adjusting a scanning antenna carried by it to capture at least RF field strength data to give a 3-Dimension representation of the transmitting antenna.

Lesser manpower is required to achieve the RF mapping; specifically, no manpower effort needed during the mapping process.

Other objects and advantages shall become apparent by reading the following detailed description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram showing a vehicle incorporating an autonomous RF mapping system embodying the present invention.

FIG. 2 is a block diagram of the RF mapping system.

FIG. 3 is a flow diagram showing the operation flow of the autonomous RF mapping system.

DETAILED DESCRIPTION OF THE INVENTION

In describing a preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, the invention is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

Referring now to FIG. 1, there is shown an autonomous vehicle 10, having an antenna 20 mounted from an elevation system 70.

With reference to the block diagram depicted in FIG. 2, an autonomous RF mapping system 25 comprises the antenna 20 for receiving an RF signal transmitted from a source 85 positioned onto the autonomous vehicle 10; a Central Processing Unit (CPU) 30 providing overall control of the autonomous vehicle 10; a navigation system 40 for calculating relative distance and direction for the autonomous vehicle 10 to circulate a test object 80 to be scanned; a vehicle control system 50; an antenna elevation means 70 being controlled by the CPU 30 to set the antenna 20 at pre-defined heights to perform scanning; and a data acquisition system 60 having a recording system for recording RF signal strength and transmitted data continuously in the course of mapping.

The operation of the RF mapping system 25 will now be described in conjunction with the flow diagram of FIG. 3.

The CPU 30 has control of the entire autonomous vehicle 10. In operation, at the start (step S100), the autonomous vehicle will be parked. Once the autonomous RF mapping system 25 is powered up, the user is required to input parameters for the RF mapping system 25 to proceed (step S110). The parameters include the type of the test object, the position of the test object, the number of scans for one circular path, the radial interval of between each circular path, and the elevation height of the antenna for each scan. A storage means (not shown) stores relevant information regarding current available test objects, for example the shape and size of the test object for user selection. Such test objects may be any kind of fighter, helicopter or the like which has at least one installed RF source 85. The user has the possibility of further specifying a number of concentric scans to be performed with specific radial intervals between each concentric circle. In order to obtain a 3-Dimensional (3D) mapping image of RF signal distribution around the test object 80, a plurality of scans are performed with various height of the antenna 20 for a same circular path or over a number of paths.

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The navigation system 40, based on Differential Global Positioning System (DGPS) or Inertial Navigation System (INS), determines its own location and calculates the relative distance and direction with respect to the test object (i.e. based on the user input location) 80 to perform the RF scanning. The location of the test object is, for example, the position of the landing gears/wheels. The calculated results send to the CPU 30 to plot a traveling path, and the CPU 30 provides steering inputs to the vehicle control system 50.

The traveling path is plotted from the original location to the initial position by the CPU 30. Based on the user input parameters, the CPU 30 further calculates a final position, which is a location where the autonomous vehicle 10

will end at once the scanning process is completed. For the initial position and the final position, the CPU 30 allocates variables, namely (r_i, h_i) and (r_f, h_f) , where r represents radius of the scanning circle and h represents the height of the antenna 20. Once the autonomous vehicle 10 has positioned itself at the initial position (r_i, h_i) , the CPU 30 sets the current position, r_c equal to r_i (step S140) and the current antenna height h_c equal to the h_i (step S141).

Based on the traveling path provided by the CPU 30, the vehicle control system 50 guides the vehicle 10 to a prescribed location, which is a starting location relative to the test object 80 to be scanned for the scanning process. At the starting location, the CPU 30 instructs the antenna elevation system 70 to set the RF receiver antenna 20 at a prescribed height to begin a circular scan.

The autonomous RF scanning system 25 starts the RF scanning (step S142) by moving along a first circular path. While scanning, the detected RF signals will be acquired and recorded in the data acquisition system 60 (step S150). This signal includes RF signal strength and RF data. After a first scan is completed, the CPU 30 will check if the autonomous vehicle 10 has returned to the initial position r_i . If in the affirmative, the CPU 30 will adjust the current antenna height to the next antenna height and set the next antenna height as the current antenna height (step S147). Such scanning process will be repeated on the first circular path until the antenna reaches the final antenna height, h_f .

The autonomous vehicle 10 moves to another circular path r_{c+1} , having a prescribed radial interval from the previous circular path, and the antenna height is restored to the initial height, h_i . Steps S141 to S146 loop until the vehicle's position and the antenna's height reach the final position and the final height (r_f, h_f) .

In case where a continuous scan is required for additional circular paths and/or additional antenna heights, the autonomous RF mapping system 25 sets

the autonomous vehicle 10 in a particular position and/or height, even if the original position of the vehicle 10 and/or the test object may now be different from the previous scan.

5 In case where a rescan is required, the RF mapping system 25 sets the autonomous RF mapping system to perform the same scan sequence for the same test object but a relocated RF source, even if the original position of the autonomous vehicle 10 and/or the location of the test object are different from the previous scan.

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 In accordance with the preferred embodiment, the components may be housed in a battery operated eight-wheeler vehicle, as such as a vehicle is able to transverse uneven terrain during field mapping of a test object.

15 The autonomous vehicle 10 is able to accurately navigate around the test object 80 without additional or external assistance from other operating staff. The navigation system 40 provides that the user need only specify the type of test object is being mapped. On some occasions, the test object 80 is not listed within the database, the user can activate mapping at a default distance from the
20 test object 80. Concurrently, the vehicle will position the antenna 20 with respect to a specified elevation.

 In order to reduce the possibility of data corruption though multi-path reflection of RF transmission, the vehicle 10 may also incorporate RF adsorbent
25 material (RAM).

 Accordingly, the combined result of accurate positioning around the test object with accurate height positioning of the antenna 20, allows a 3D image representing the RF radiation pattern of the mounted transmitting antenna 85 to
30 be obtained. A purpose of the user selecting a test object from a database is such that a solid outline of the object can be superimposed on the 3-Dimensional

radiation pattern, and this may give a useful indication which elements (e.g. wings) of the object cause discontinuities or interference in the radiation pattern.

5 A purpose for acquiring RF data in addition to field strength is to compare with the original data to detect bit errors or the like, which would indicate a non-optional positioning of a transmitting antenna.

10 While the invention has been described with respect to preferred embodiment, it will be clear to those skilled in the art that modifications and improvements may be made to the invention without departing from the spirit and scope of the invention. Therefore, the invention is not to be limited by the specific illustrative embodiment, but only by the scope of the appended claims.

CLAIMS

1. An autonomous vehicle operable to traverse a scanning path around a test object having a radio frequency signal source, said vehicle comprising :
 - a height controllable antenna mounted onto the autonomous vehicle;
 - a Central Processing Unit (CPU) providing control of the autonomous vehicle;
 - a navigation system for calculating relative distance and direction for the autonomous vehicle's scanning path around the test object;
 - a vehicle control system responsive to said CPU for positioning the vehicle at an initial scanning position and for causing traversal of the scanning path;
 - an antenna elevation system being controlled by the CPU to set the antenna to one or more heights during the scanning path;
 - a data acquisition system for acquiring and storing at least RF signal strength continuously in the course of said scanning path; and
 - a user input means for a user to input a reference location for said test object, said scanning path and said one or more heights, and said navigation system has a positioning system and calculates said relative distance from said reference location and the location of the vehicle.
2. The autonomous vehicle according to claim 1, wherein the data acquisition system further records RF data within the acquired data.
3. The autonomous vehicle according to any one of the preceding claims, wherein said CPU generates a 3-Dimensional representation of said scanned RF signal strength.
4. The autonomous vehicle according to claim 3, further comprising a memory for storing a plurality of test object data selectable by said user that gives a representation of the test object for superimposition on said 3-Dimensional representation.

5. A method for mapping the radiation pattern of transmitting antenna carried by an object, comprising the steps of :
 - (a) an autonomous vehicle locating itself positionally;
 - (b) the vehicle determining the location of the object and determining a start point of scanning path with reference to the object; and
 - (c) the vehicle traversing the scanning path and adjusting a scanning antenna carried by it to capture at least RF field strength data to give a 3-Dimensional representation of the transmitting antenna.
6. The method according to claim 5, further comprising the steps of a user inputting a reference location for said test object; and wherein said scanning path is determined from said reference location and the vehicles instantaneous position.
7. The method according to claim 6, wherein said a user inputs said scanning path and adjustment of said scanning antenna.
8. The method according to any one of claims 5 to 7, further comprising the step of recording RF data within the captured data.
9. The method according to any one of claims 5 to 8, further comprising the step of generating a 3-Dimensional representation of said captured RF signal strength.
10. The method according to claim 9, further comprising the step of superimposing a representation of the test object on said 3-dimensional representation, wherein said representation of the test object are found from a plurality of test object data selectable by said user.