



US 20250266908A1

(19) United States

(12) Patent Application Publication

Hiller

(10) Pub. No.: US 2025/0266908 A1

(43) Pub. Date: Aug. 21, 2025

(54) HONEYCOMB-LIKE LASER BEAM SCAN PATTERN

H04W 64/00 (2009.01)*H04W 84/06* (2009.01)

(71) Applicant: The Boeing Company, Arlington, VA (US)

(52) U.S. Cl.

CPC *H04B 10/118* (2013.01); *H04B 10/1129* (2013.01); *H04W 64/003* (2013.01); *H04W 84/06* (2013.01)

(72) Inventor: Nathan D. Hiller, Irvine, CA (US)

(57)

ABSTRACT

(21) Appl. No.: 18/829,853

A method for pointing a laser beam. The laser beam is directed at a central location in a search area in which a satellite is expected to be located. The laser beam is moved to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location. The next location becomes a current location for the laser beam. A number of scan parameters is adjusted during a movement of the laser beam to scan the search area. The laser beam is continued to be moved from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the object has received the laser beam.

Related U.S. Application Data

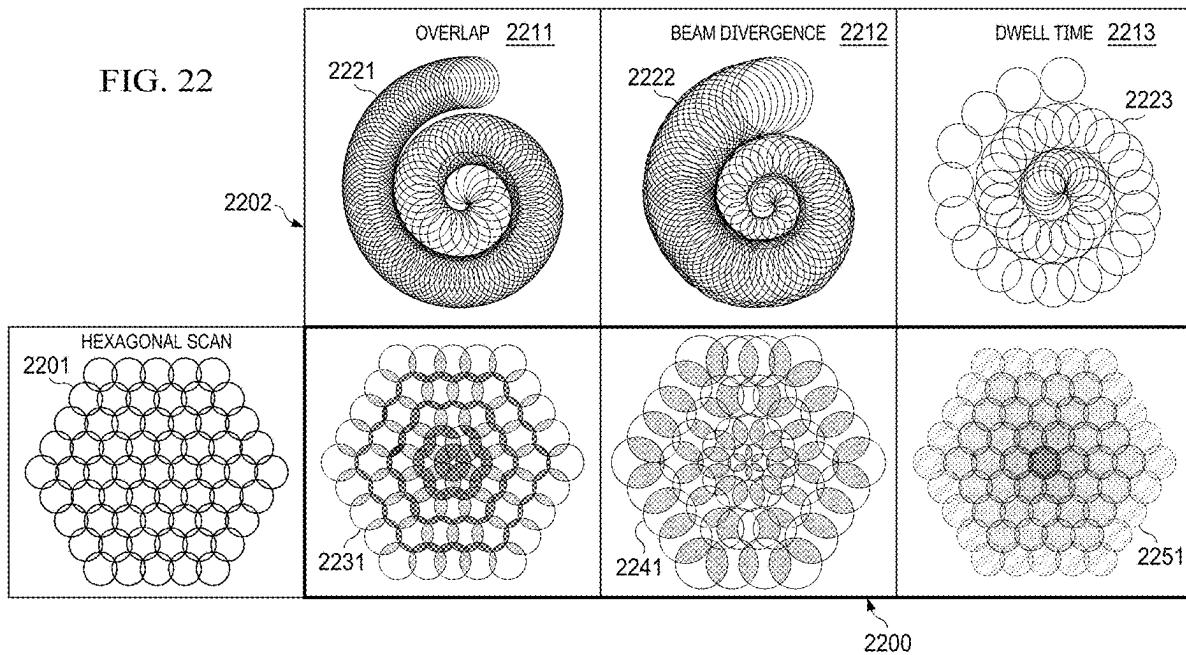
(63) Continuation-in-part of application No. 18/442,914, filed on Feb. 15, 2024.

Publication Classification

(51) Int. Cl.

H04B 10/118 (2013.01)
H04B 10/112 (2013.01)

FIG. 22



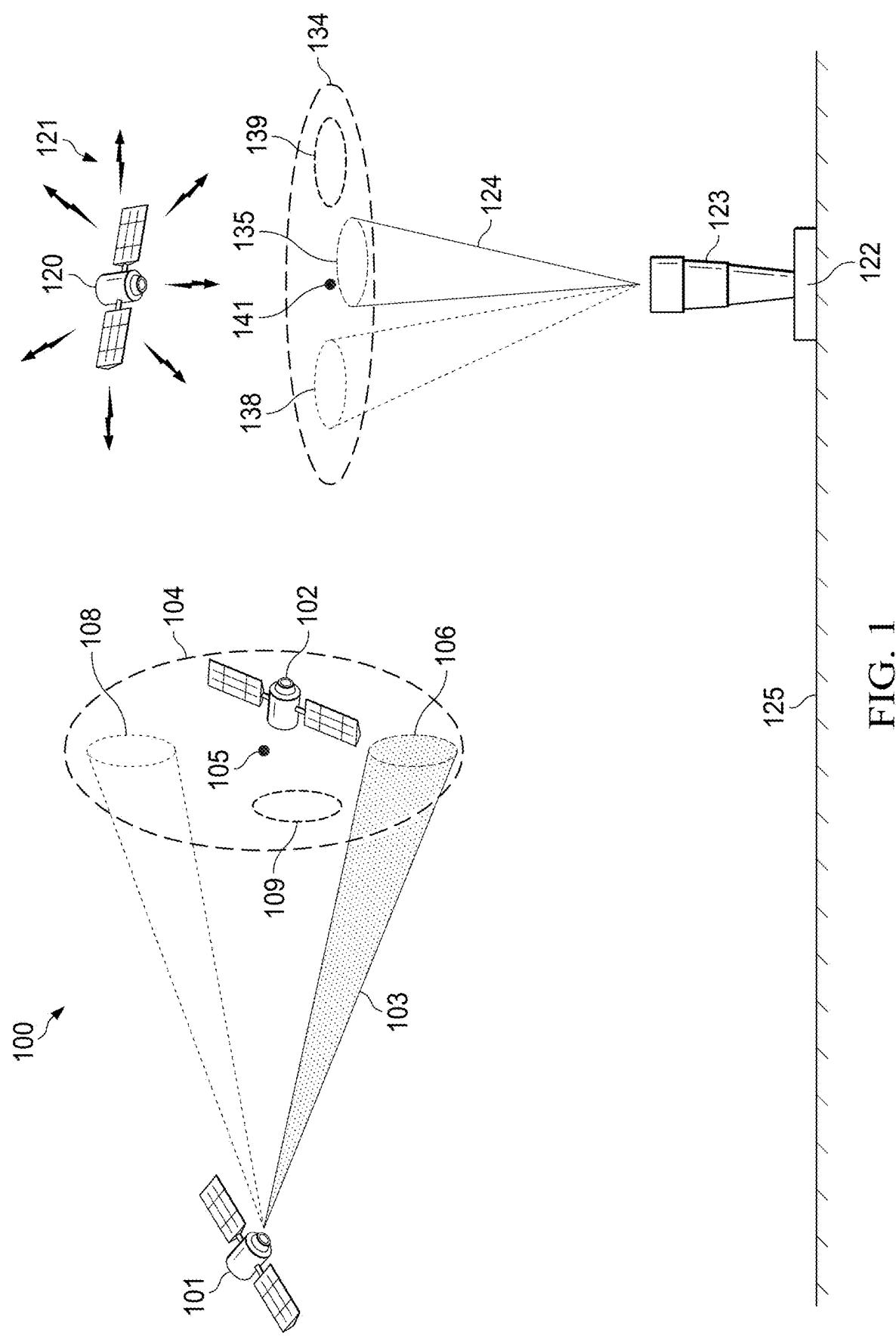
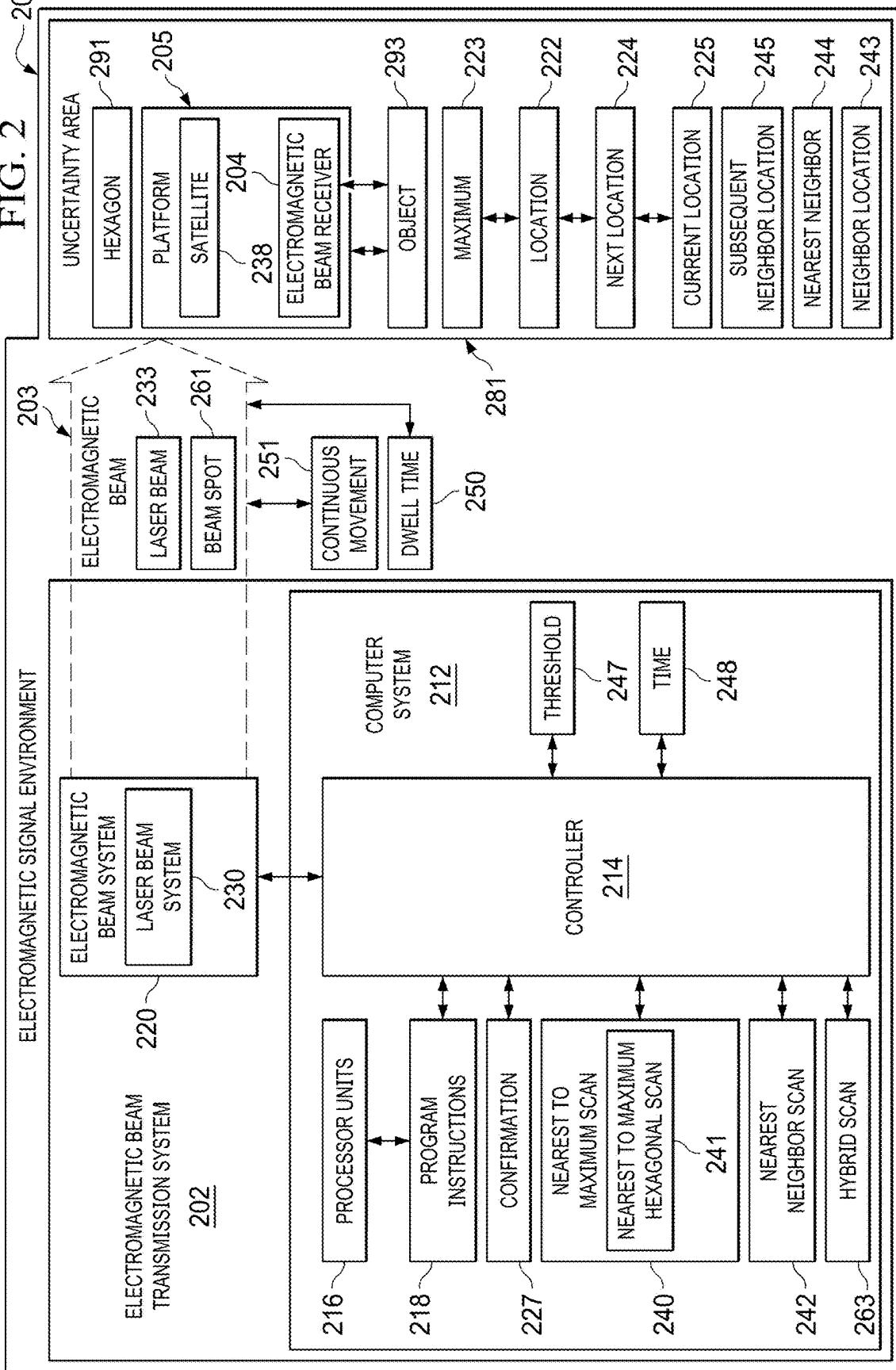


FIG. 1

FIG. 2 200



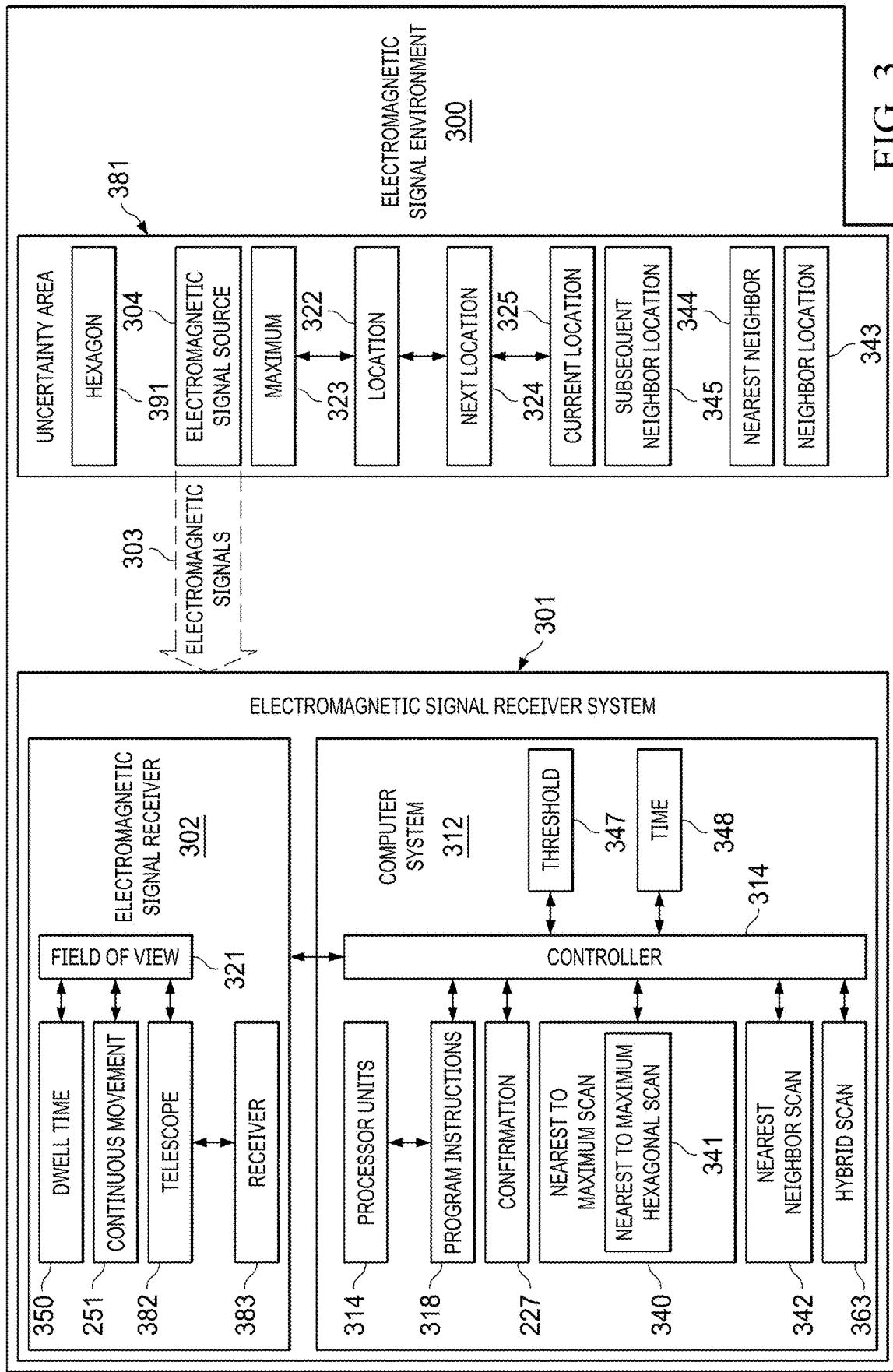


FIG. 3

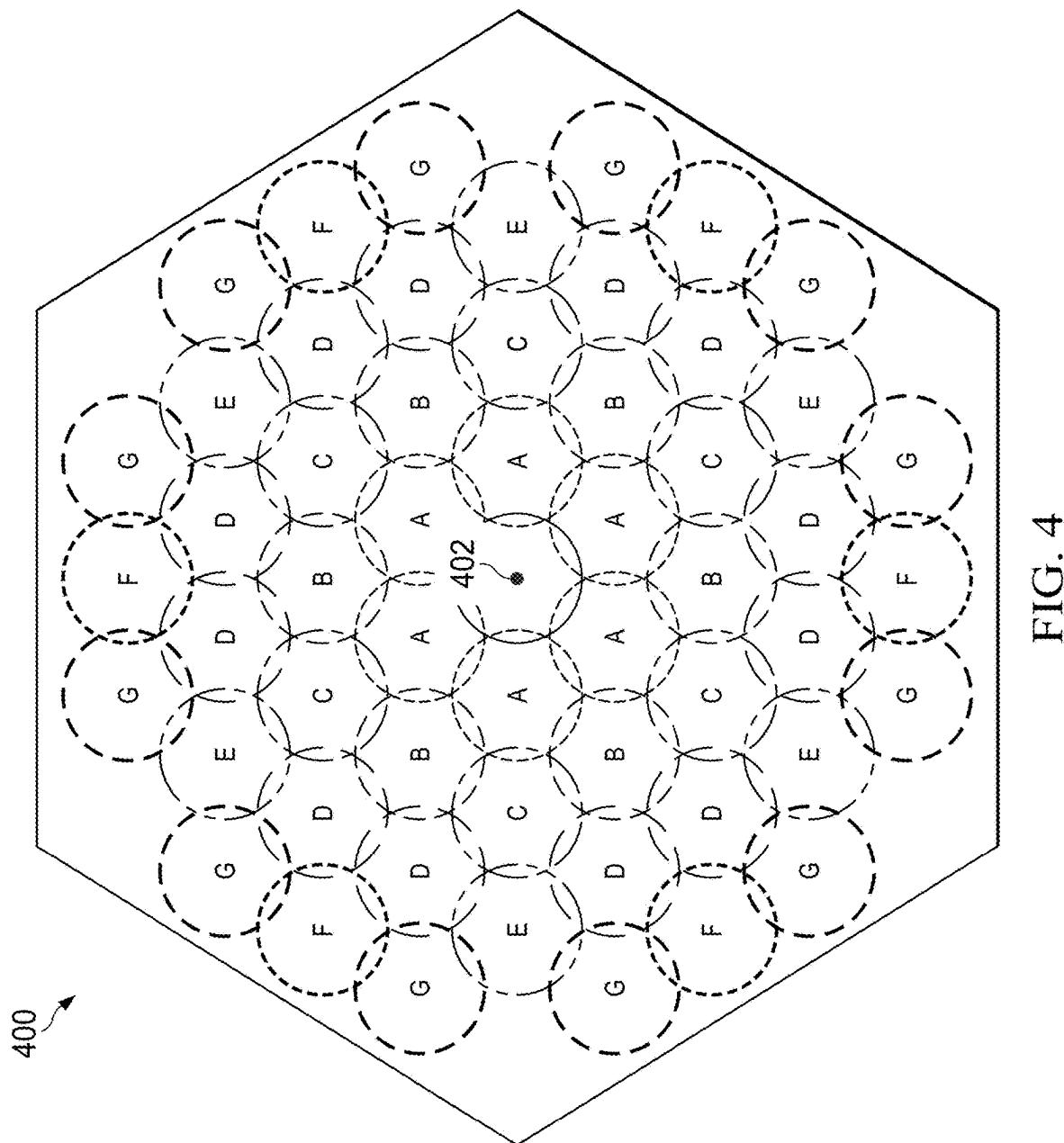


FIG. 4

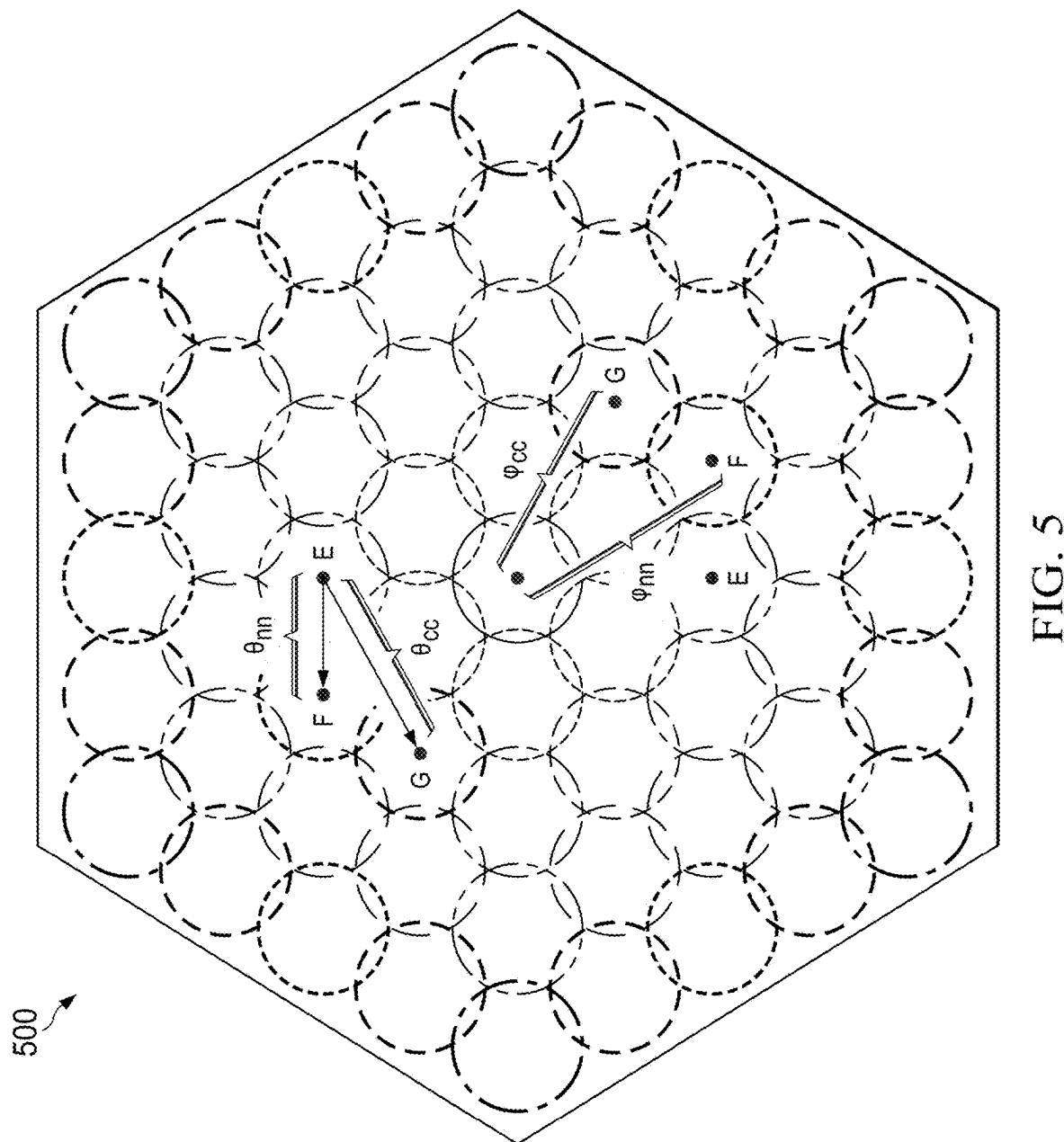


FIG. 5

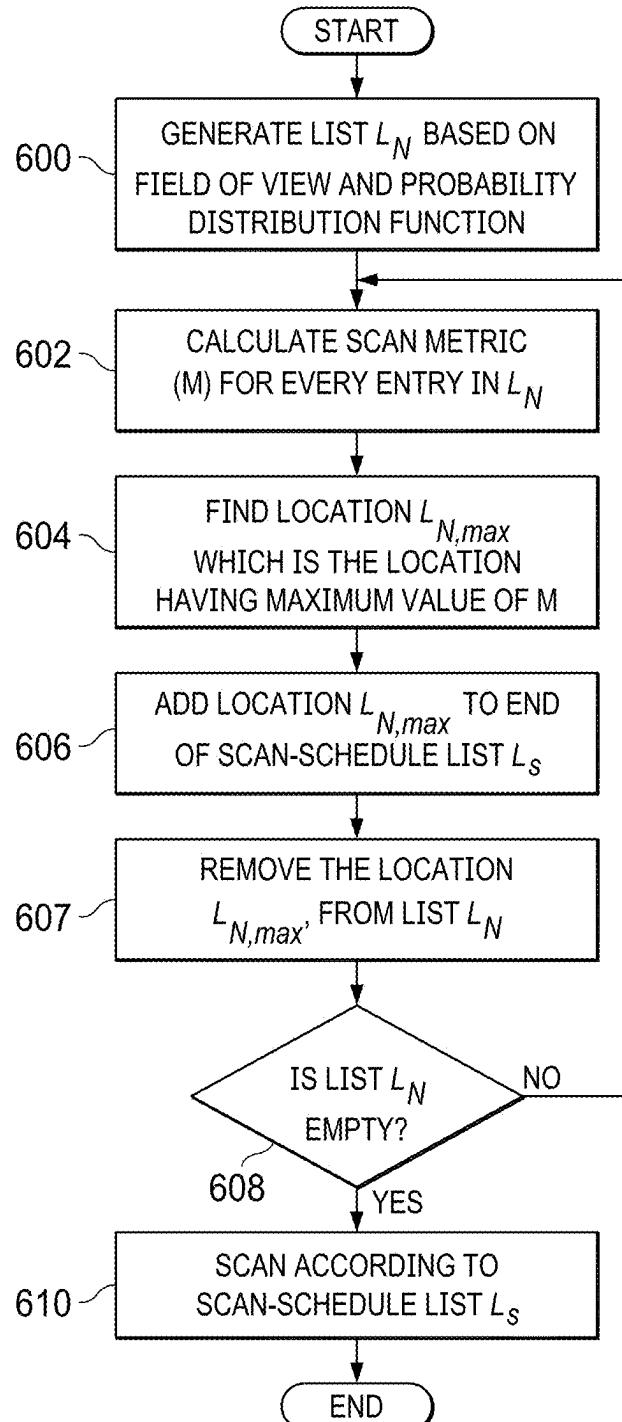


FIG. 6

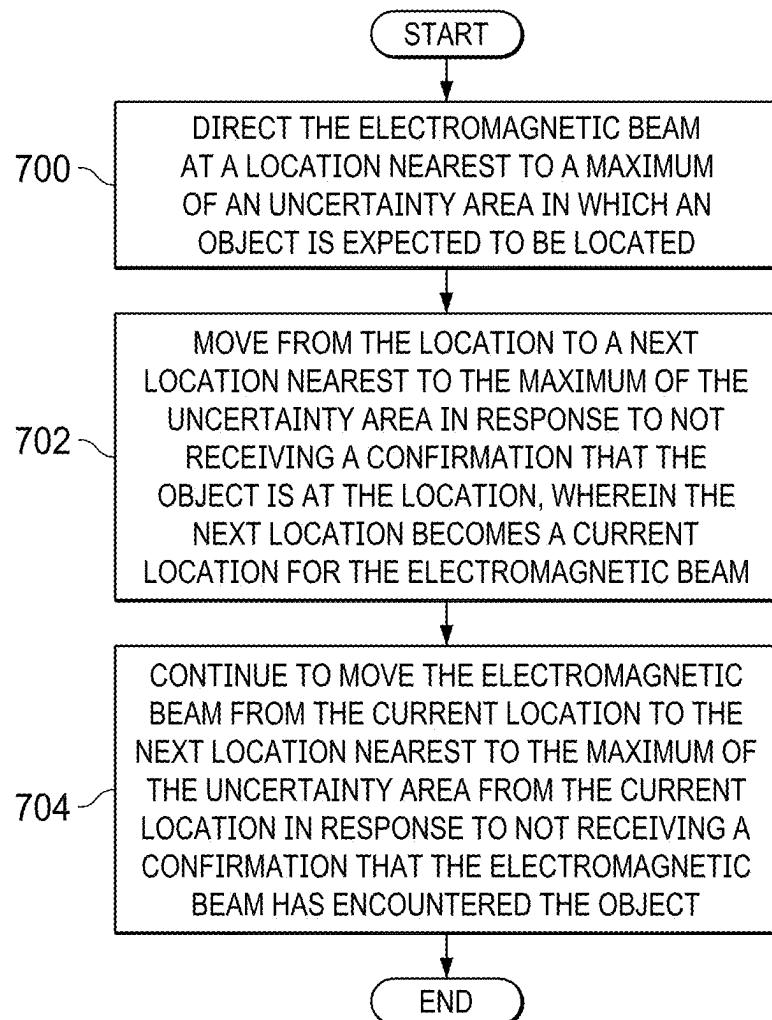


FIG. 7

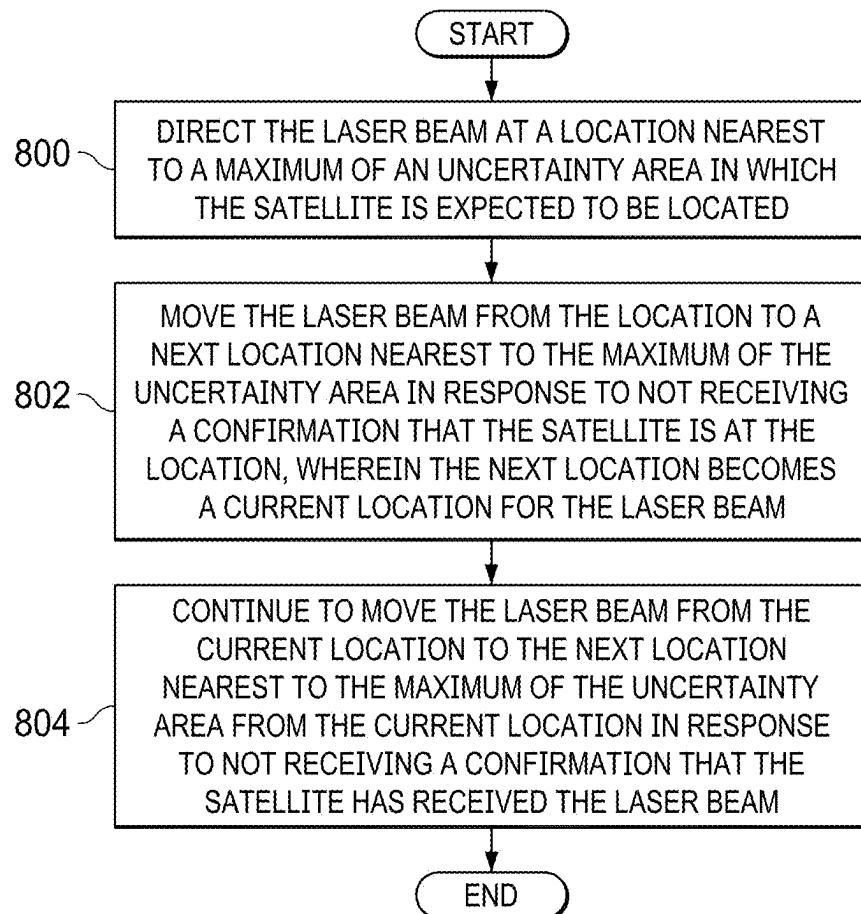
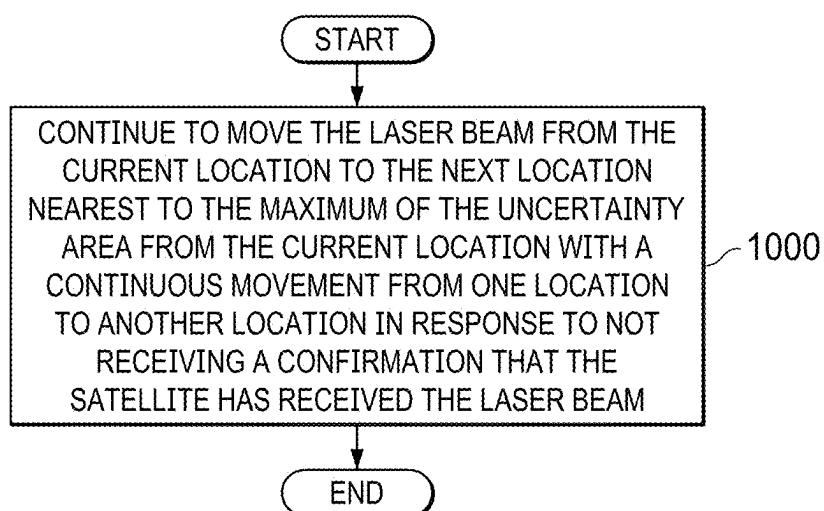
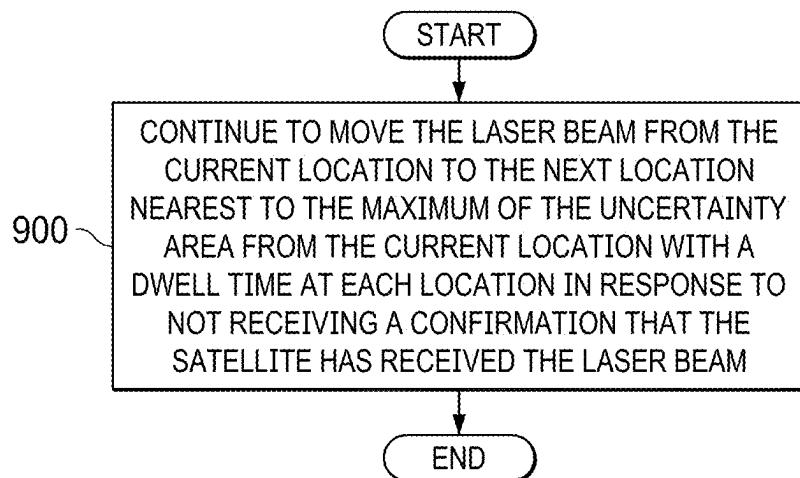
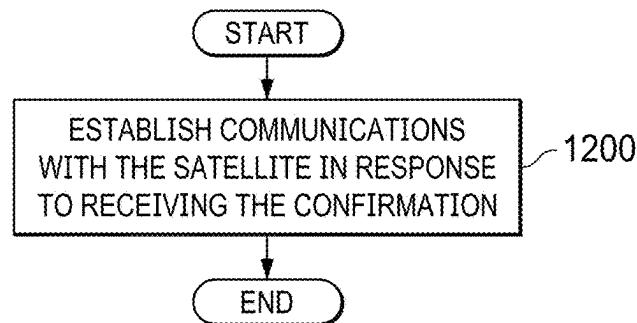
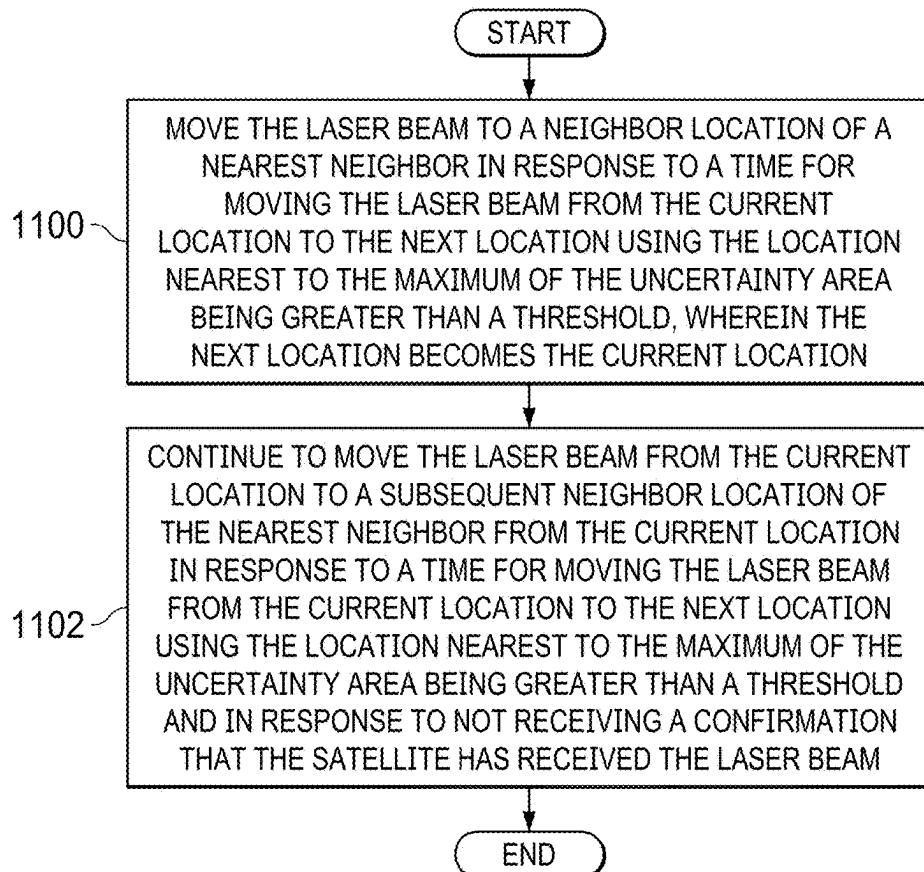


FIG. 8





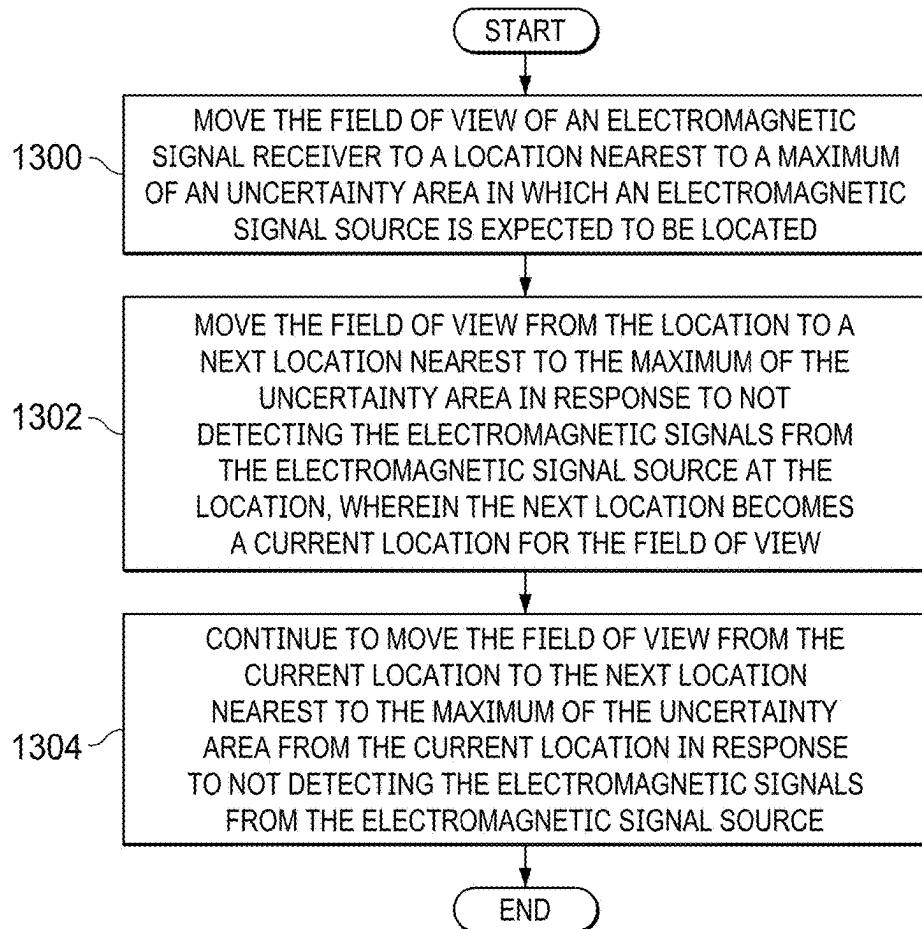


FIG. 13

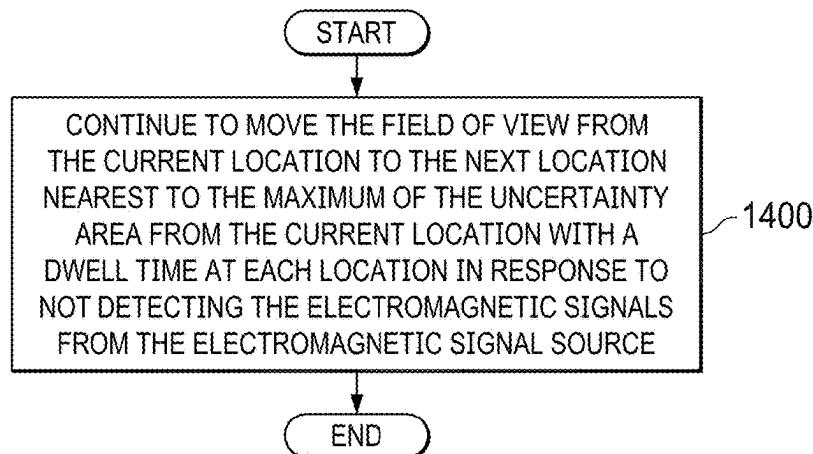


FIG. 14

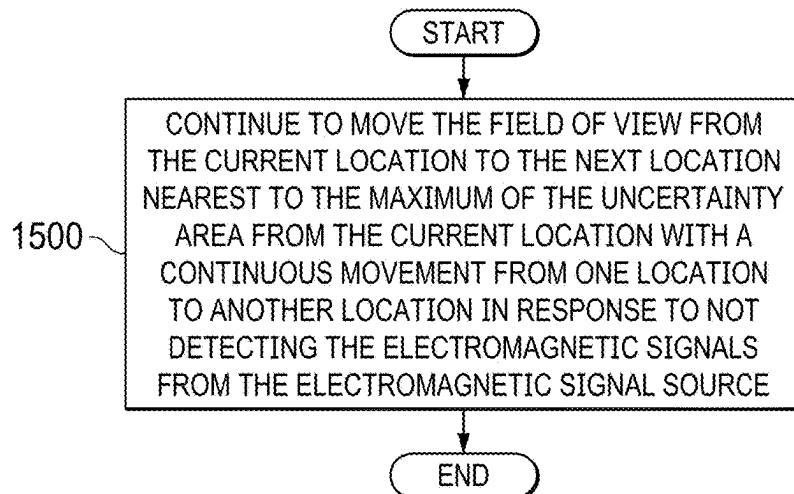


FIG. 15

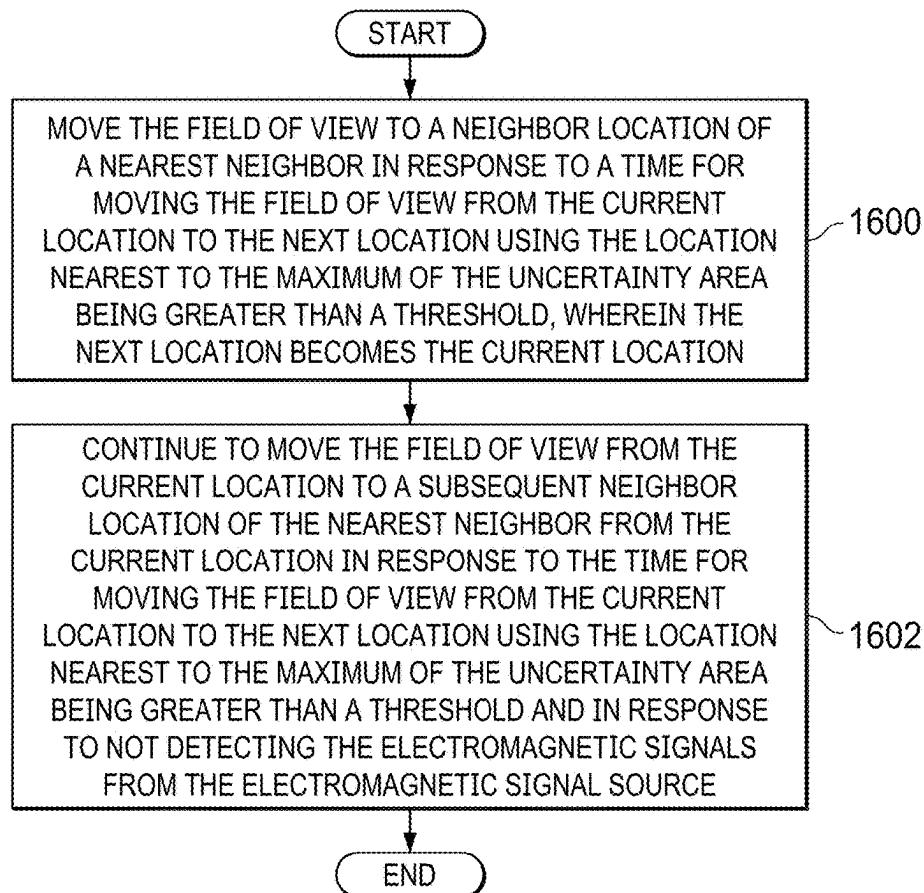


FIG. 16

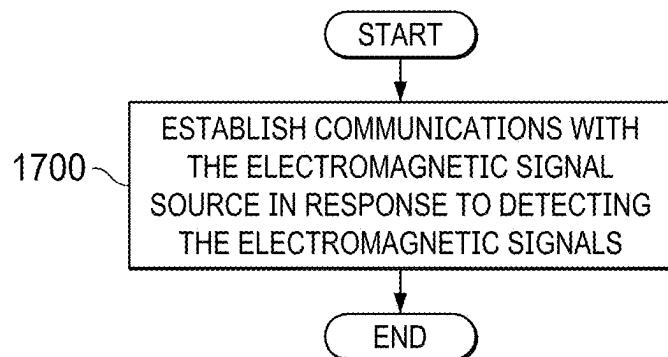


FIG. 17

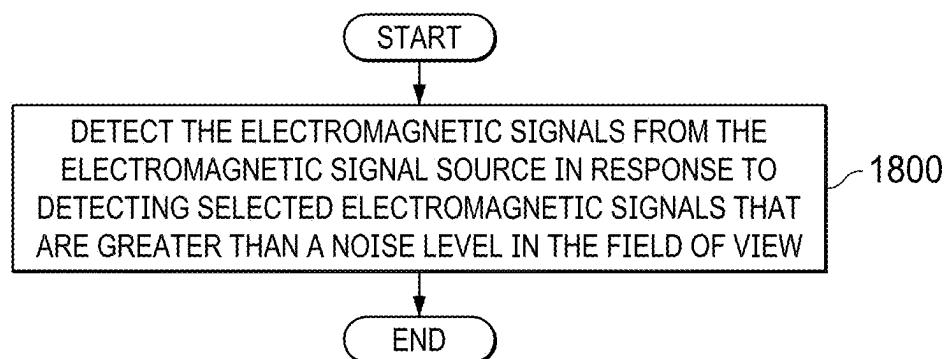


FIG. 18

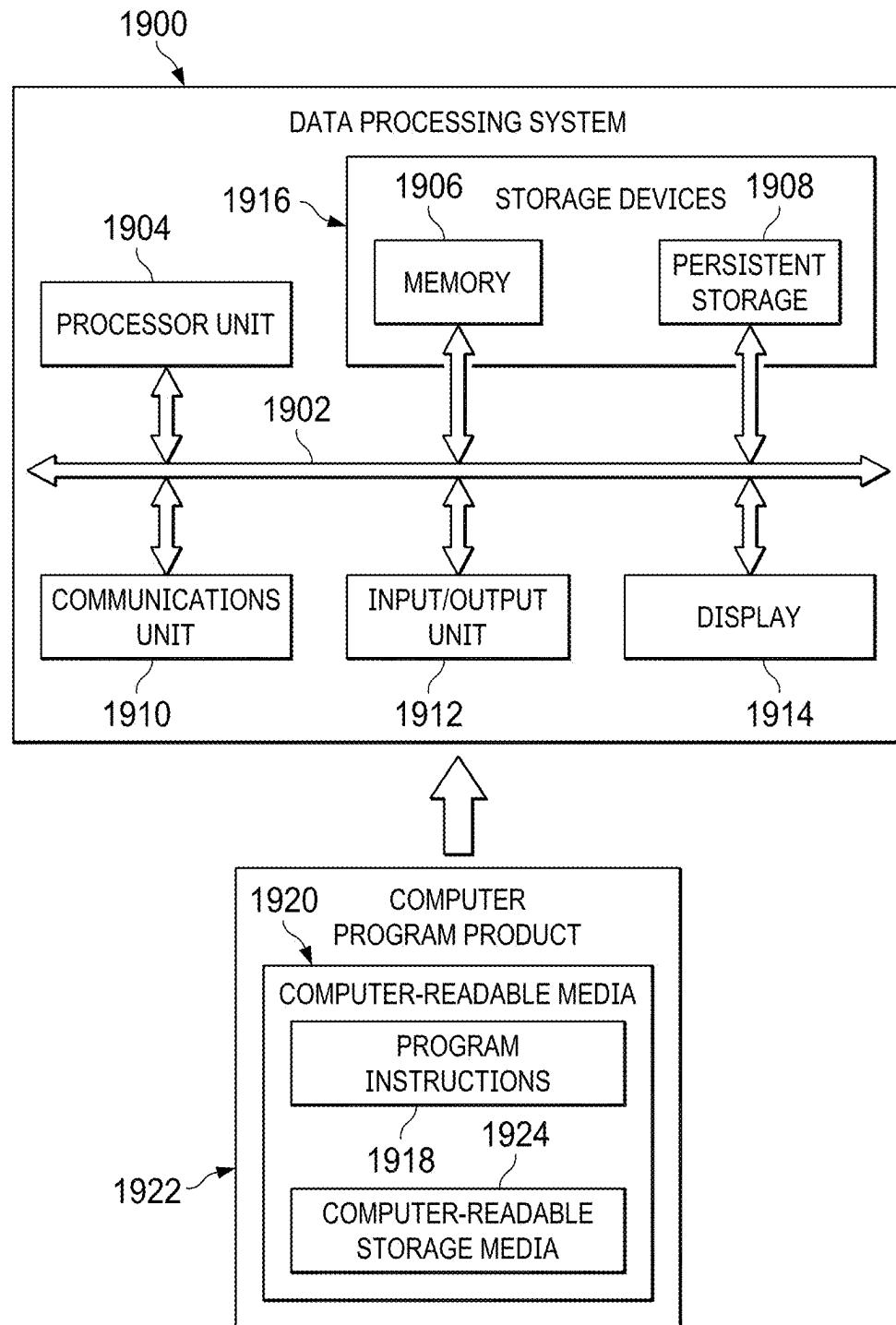
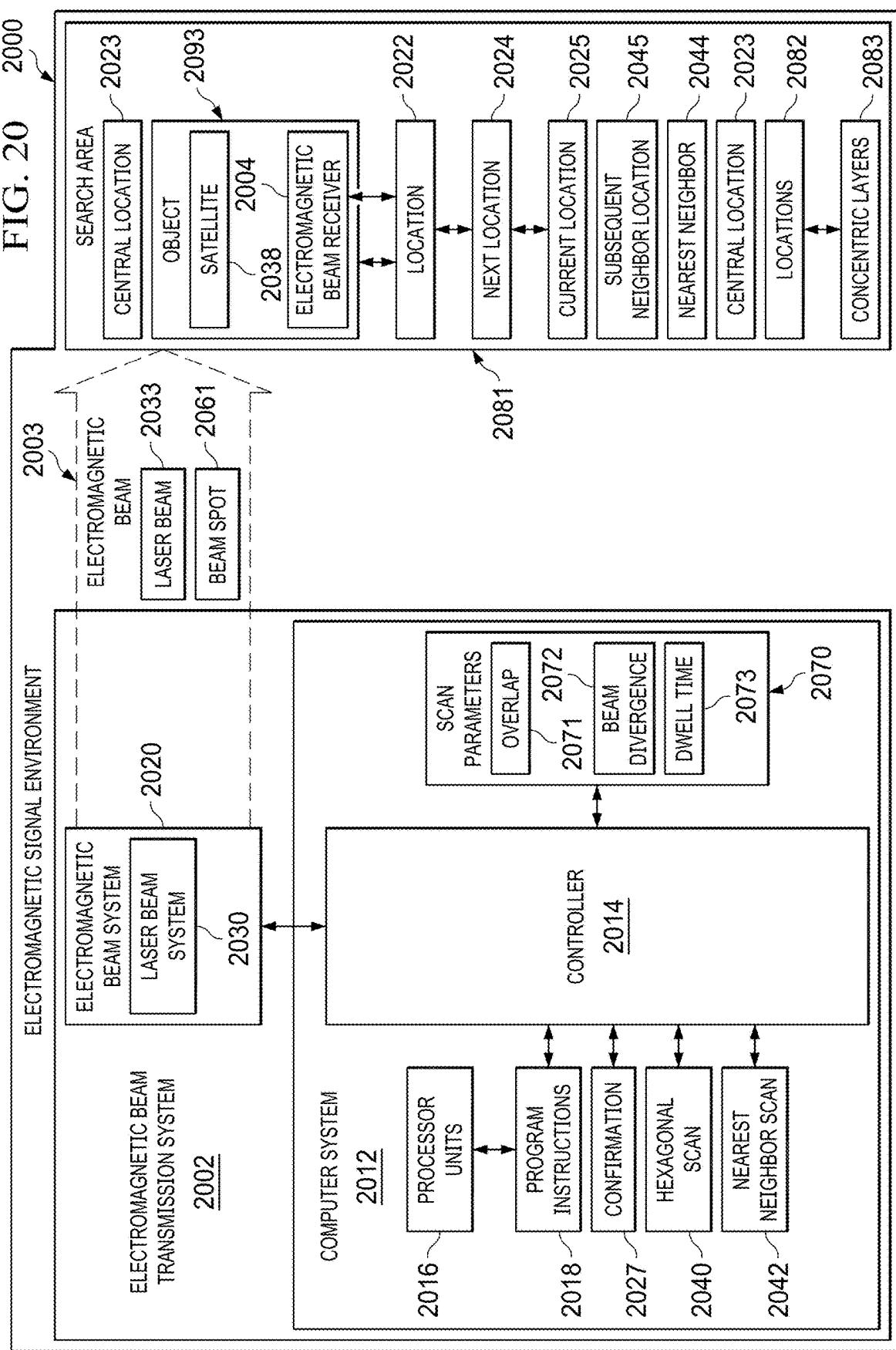


FIG. 19



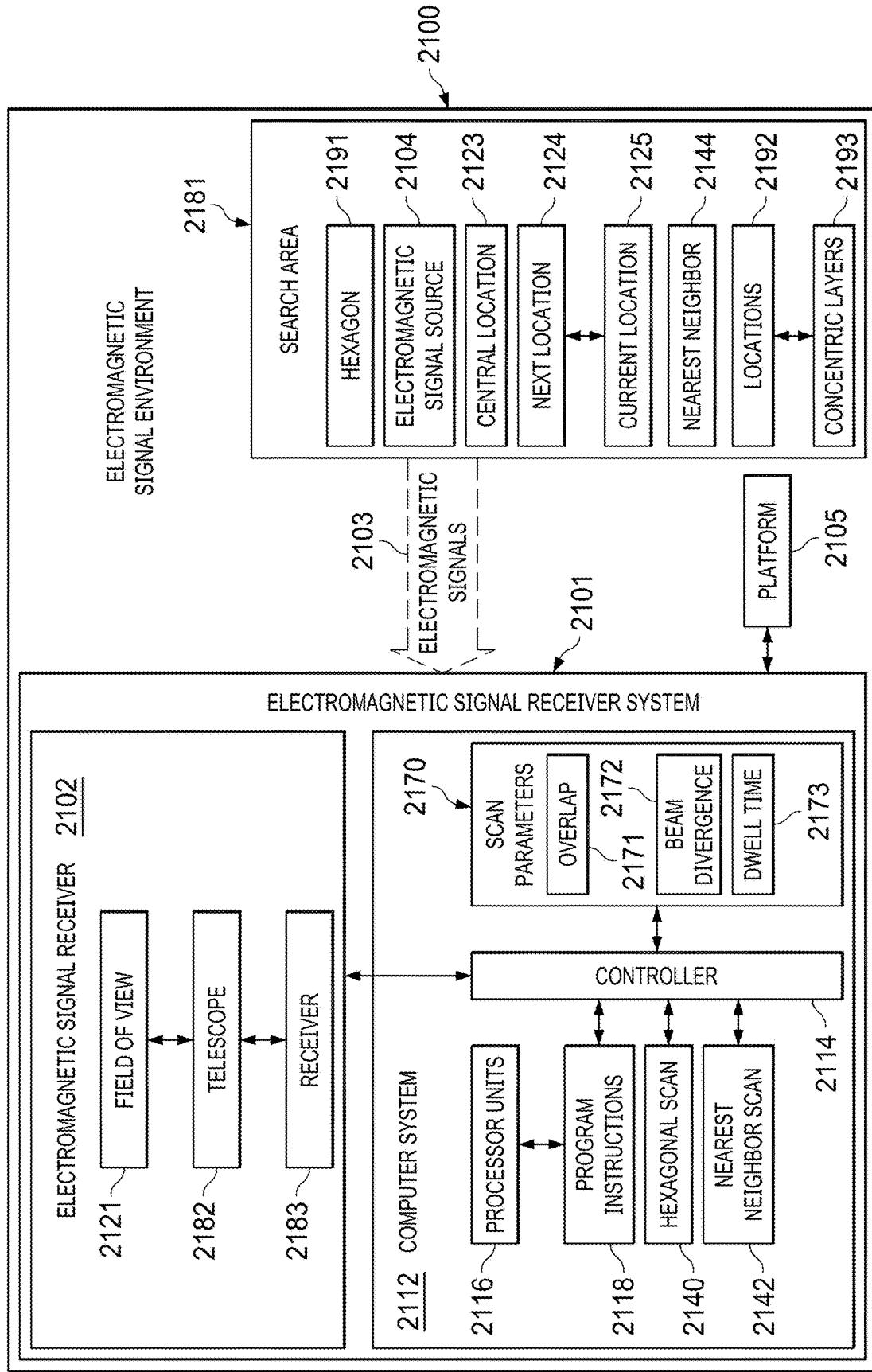


FIG. 21

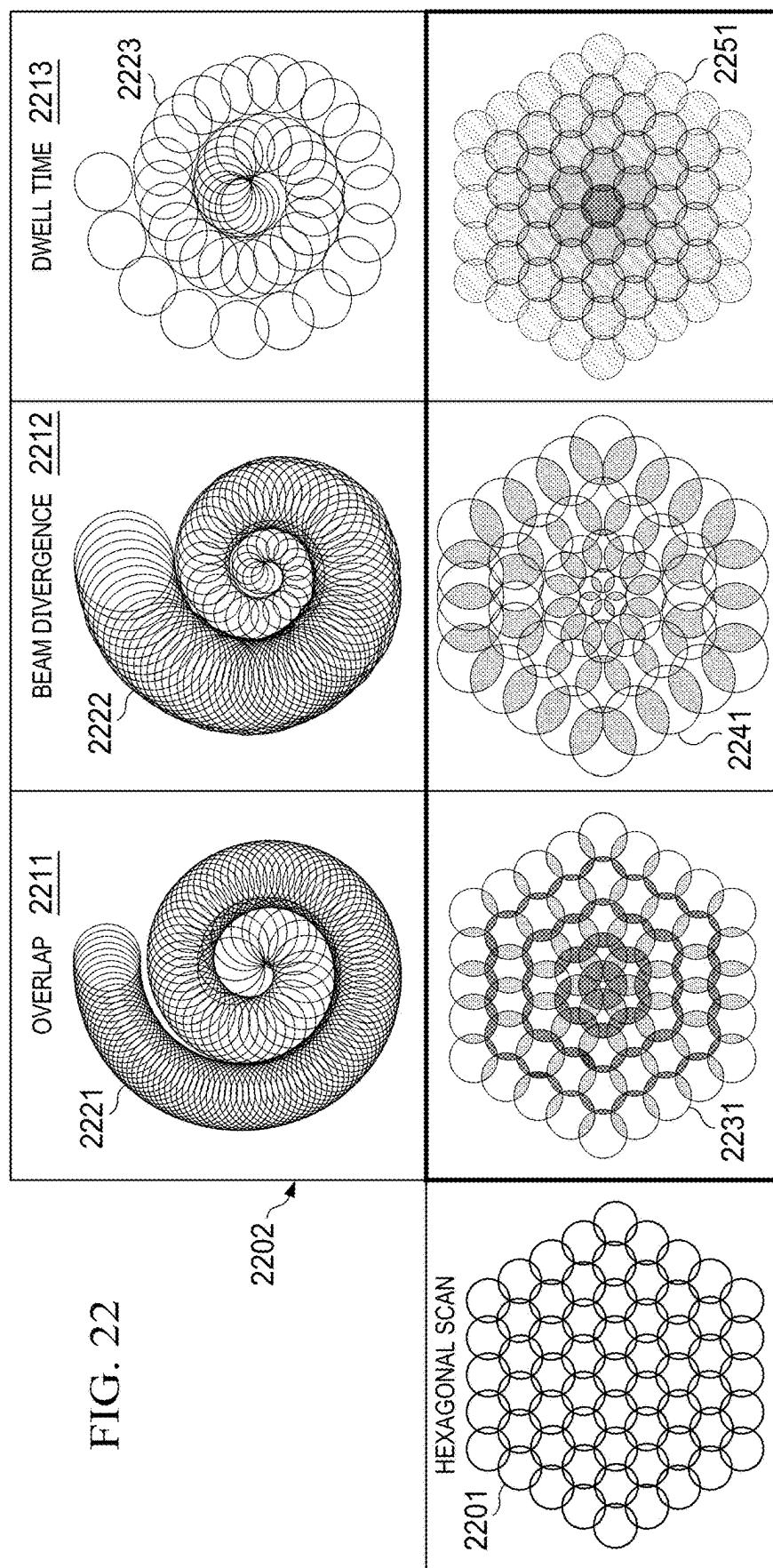


FIG. 22

FIG. 22

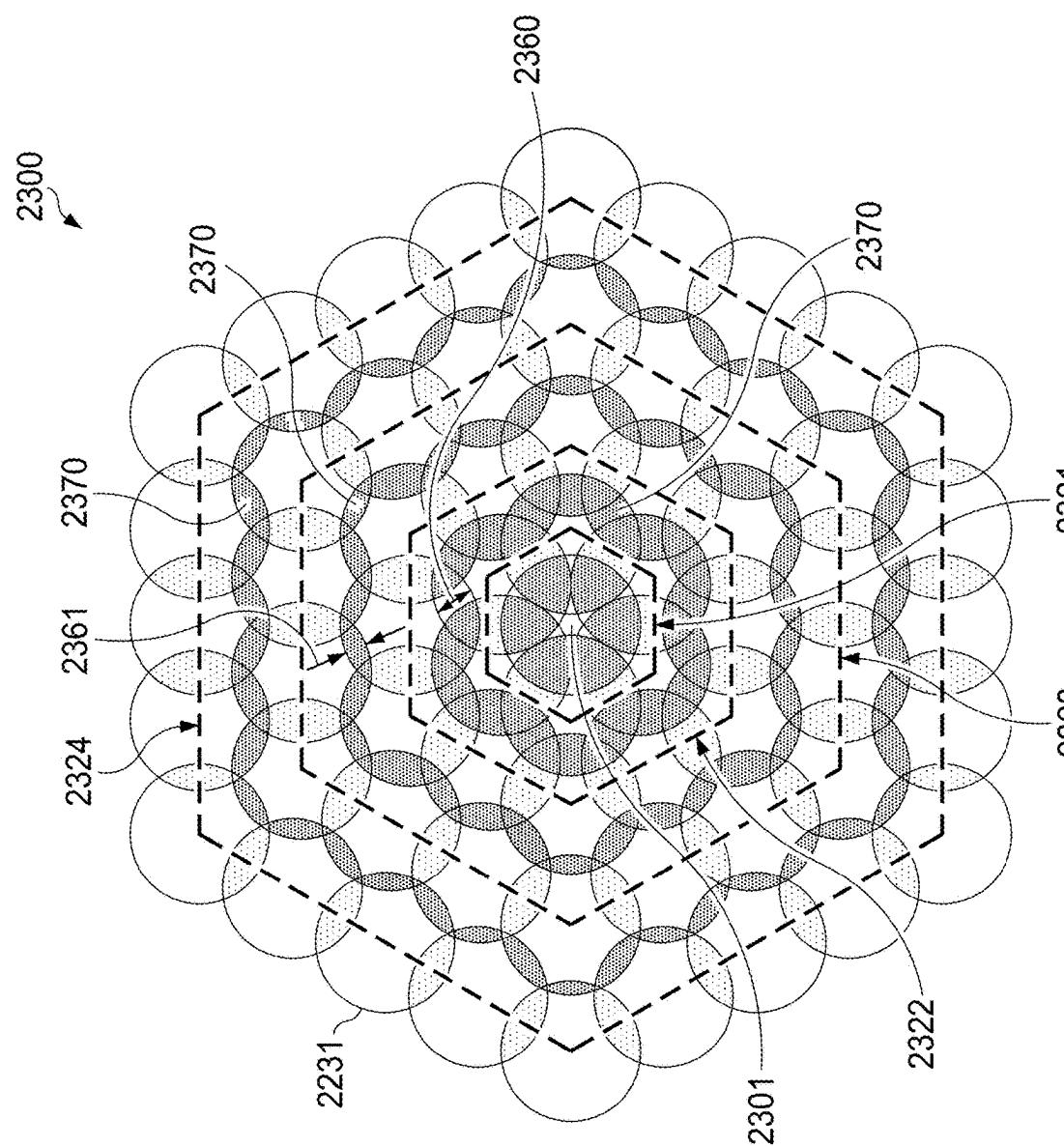


FIG. 23

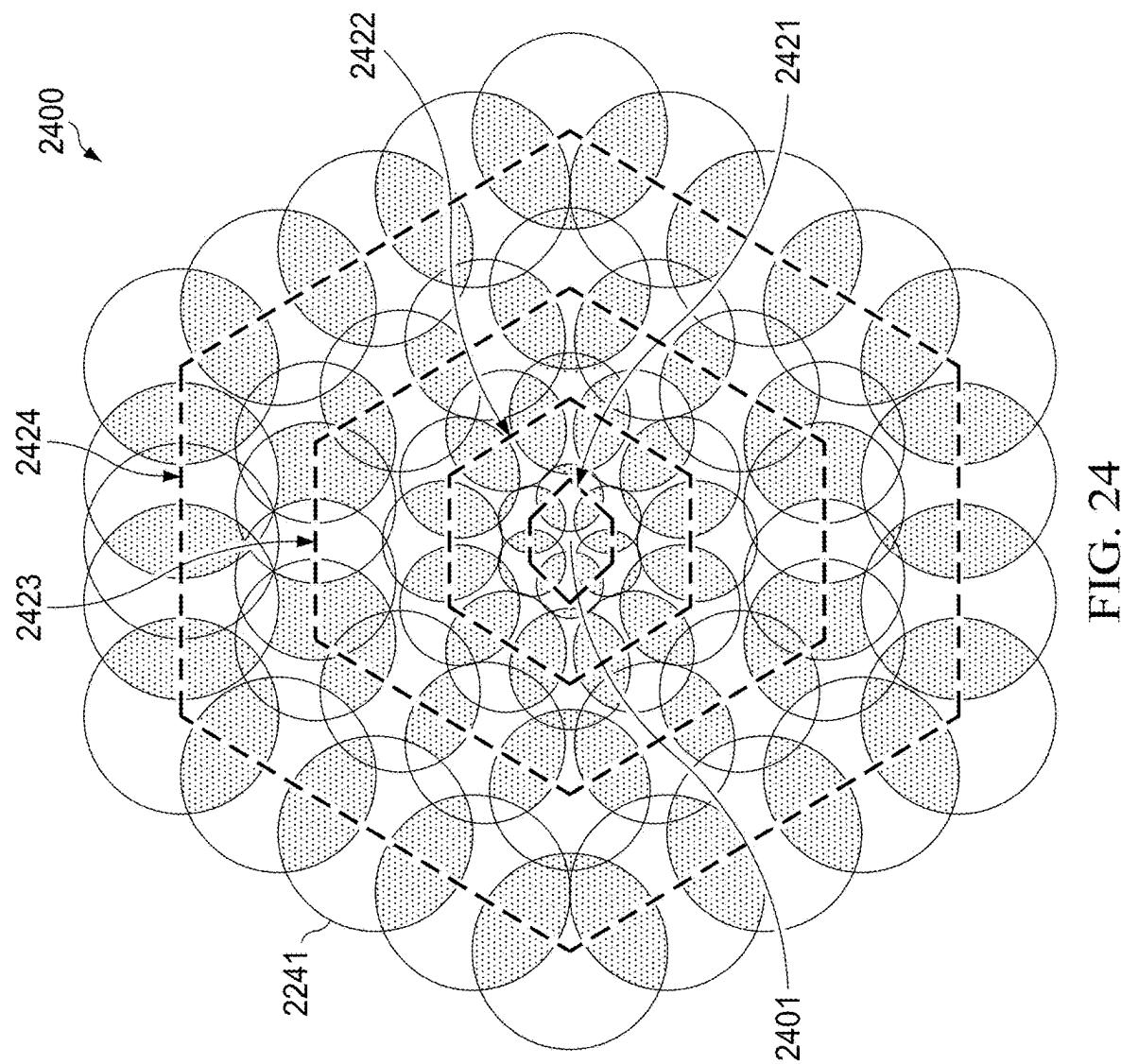


FIG. 24

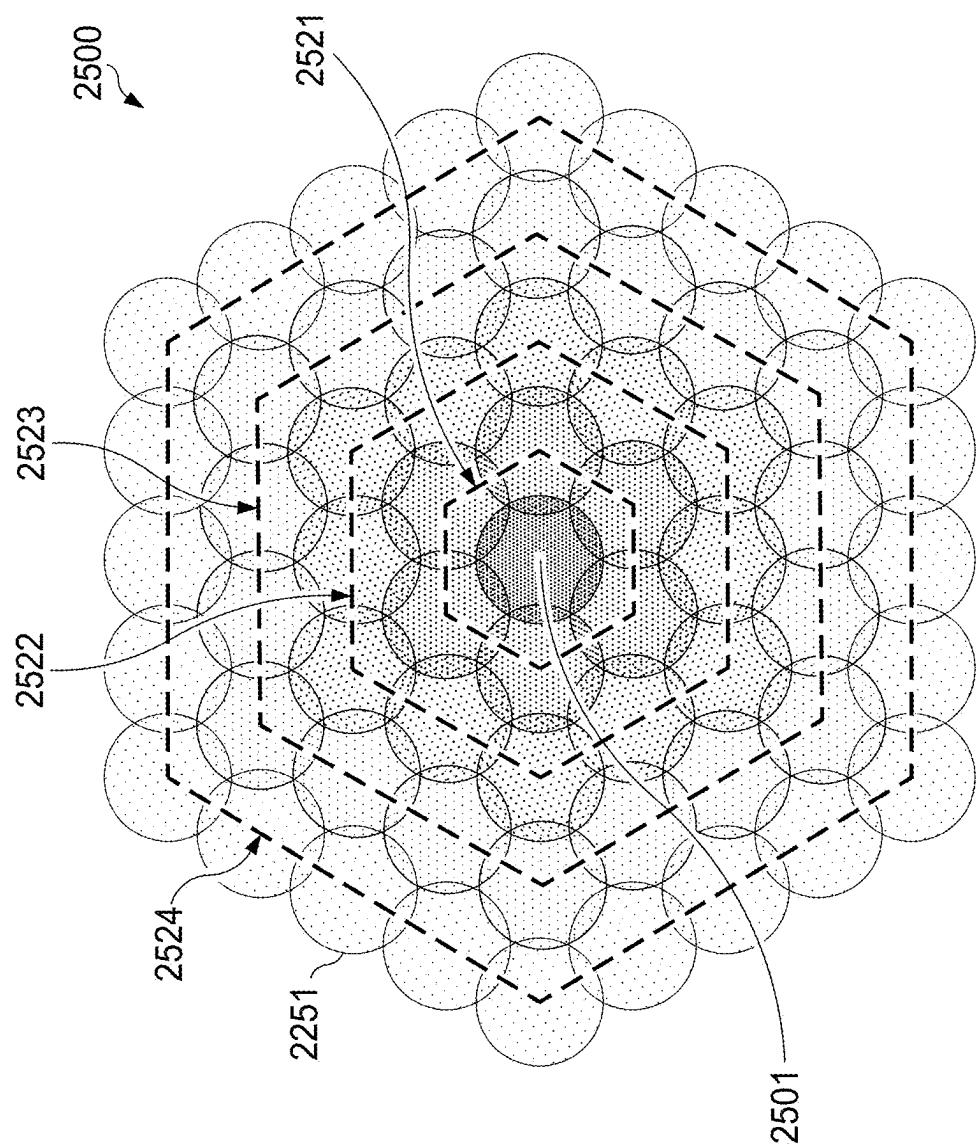


FIG. 25

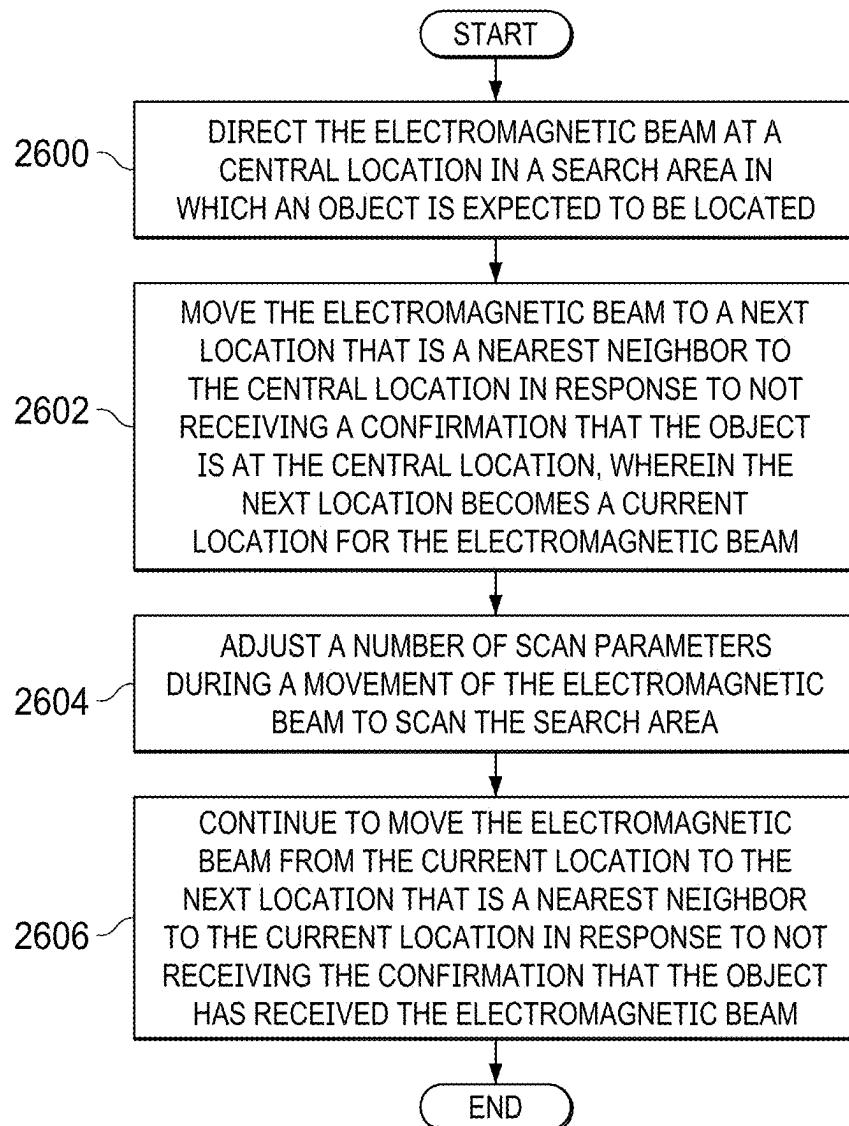


FIG. 26

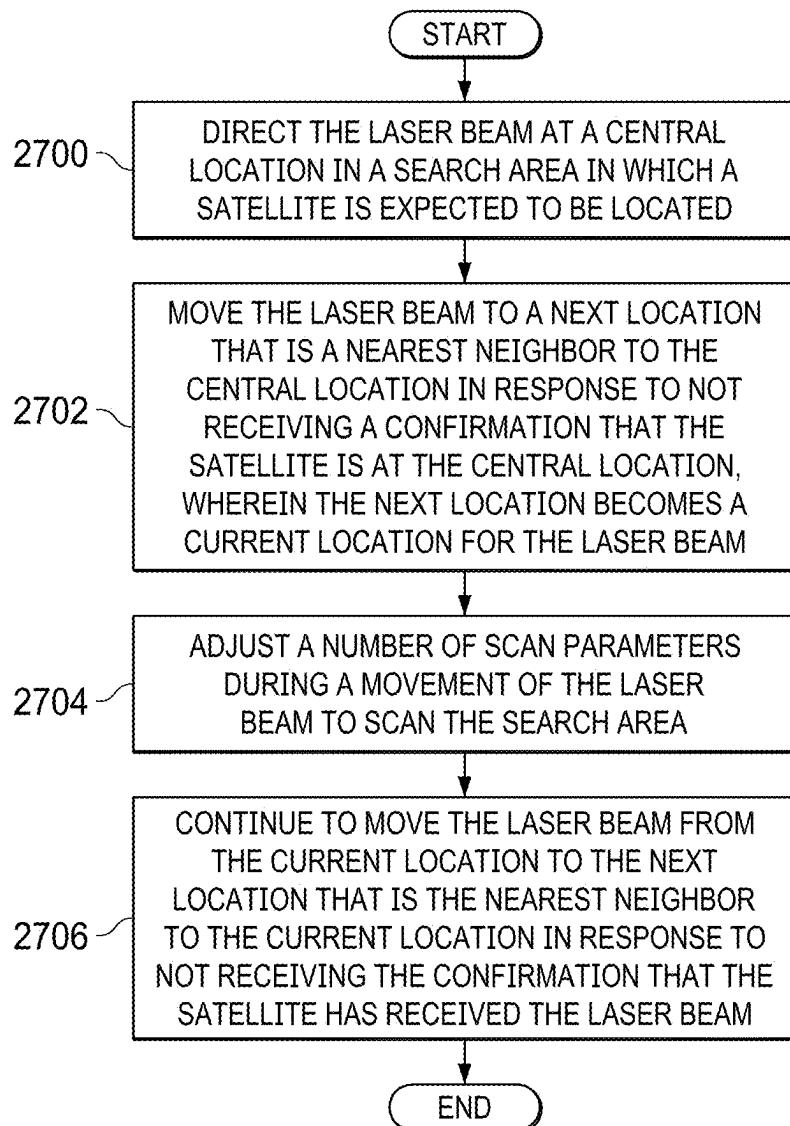


FIG. 27

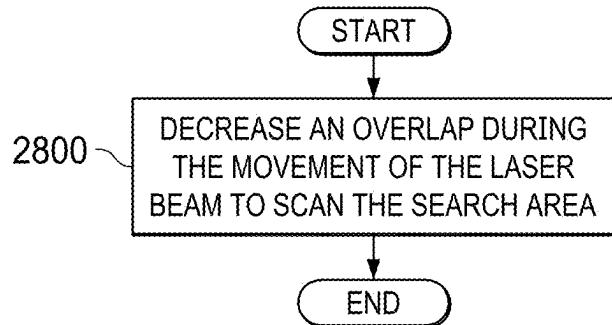


FIG. 28

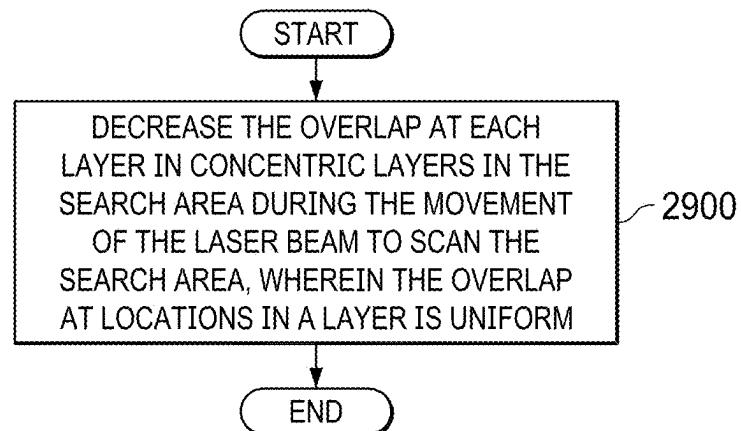


FIG. 29

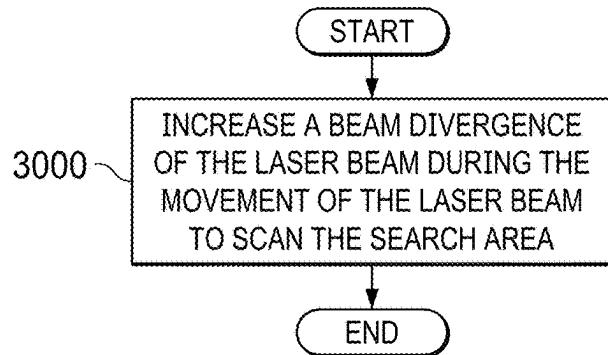


FIG. 30

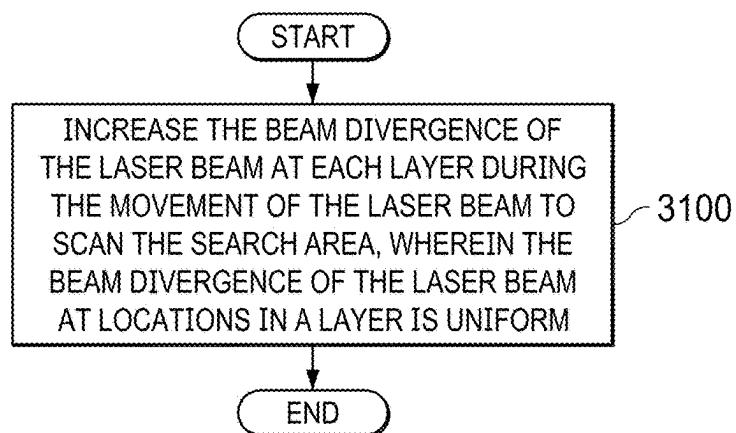


FIG. 31

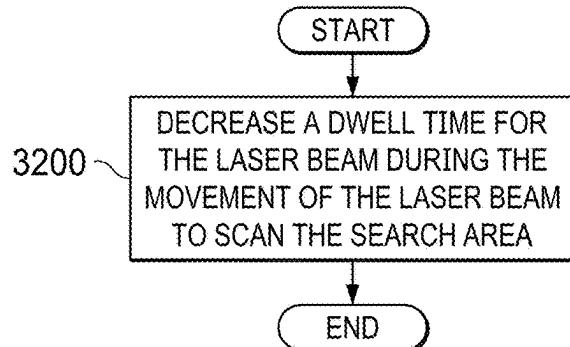


FIG. 32

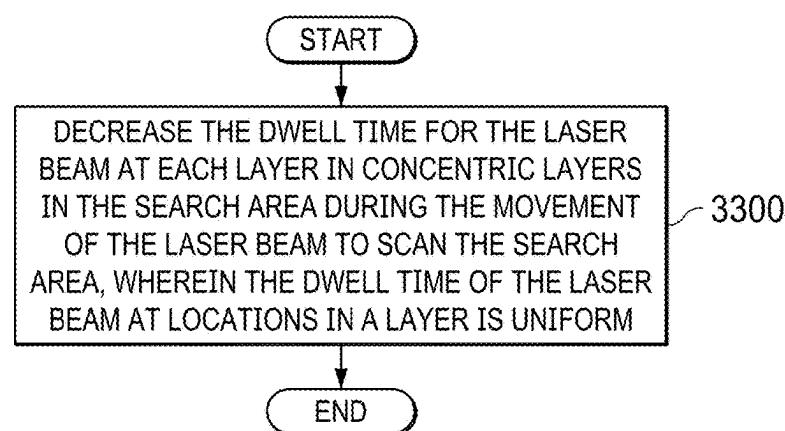


FIG. 33

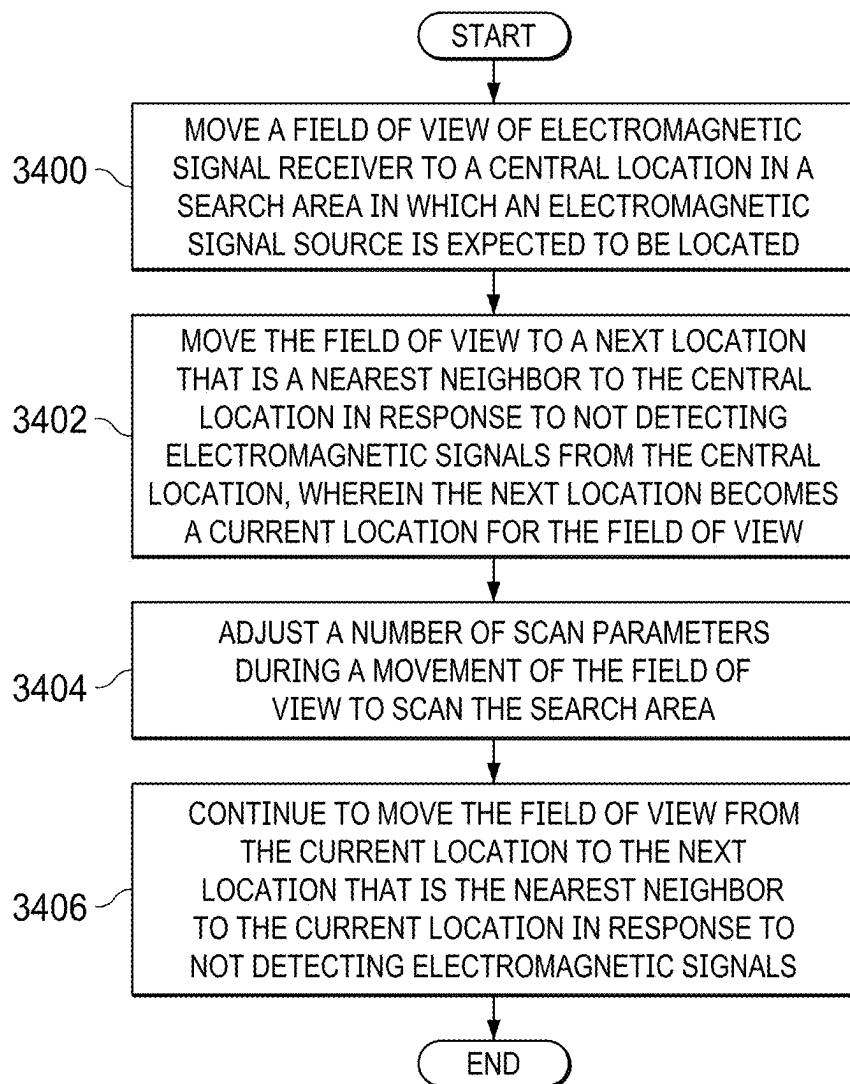
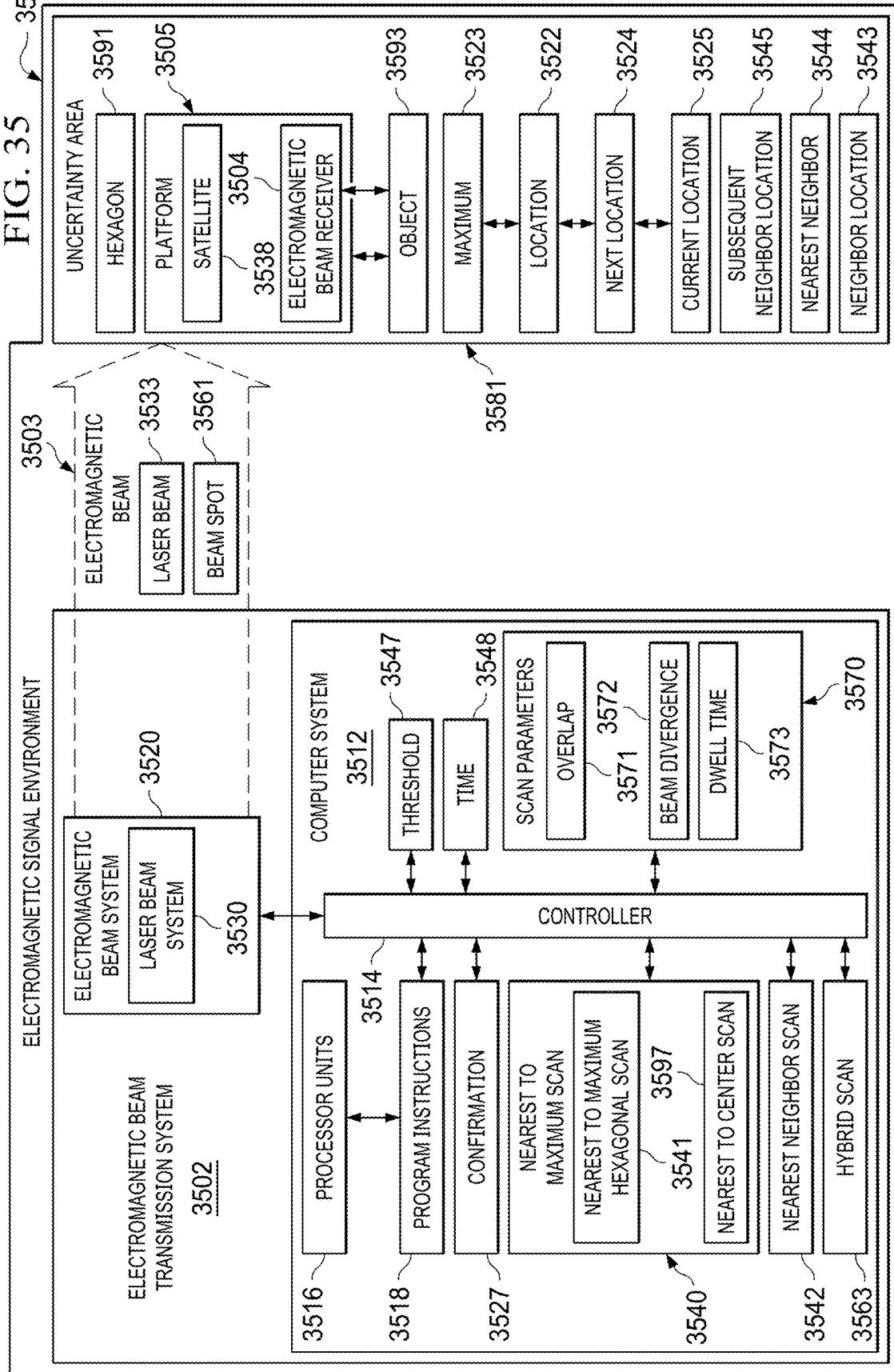
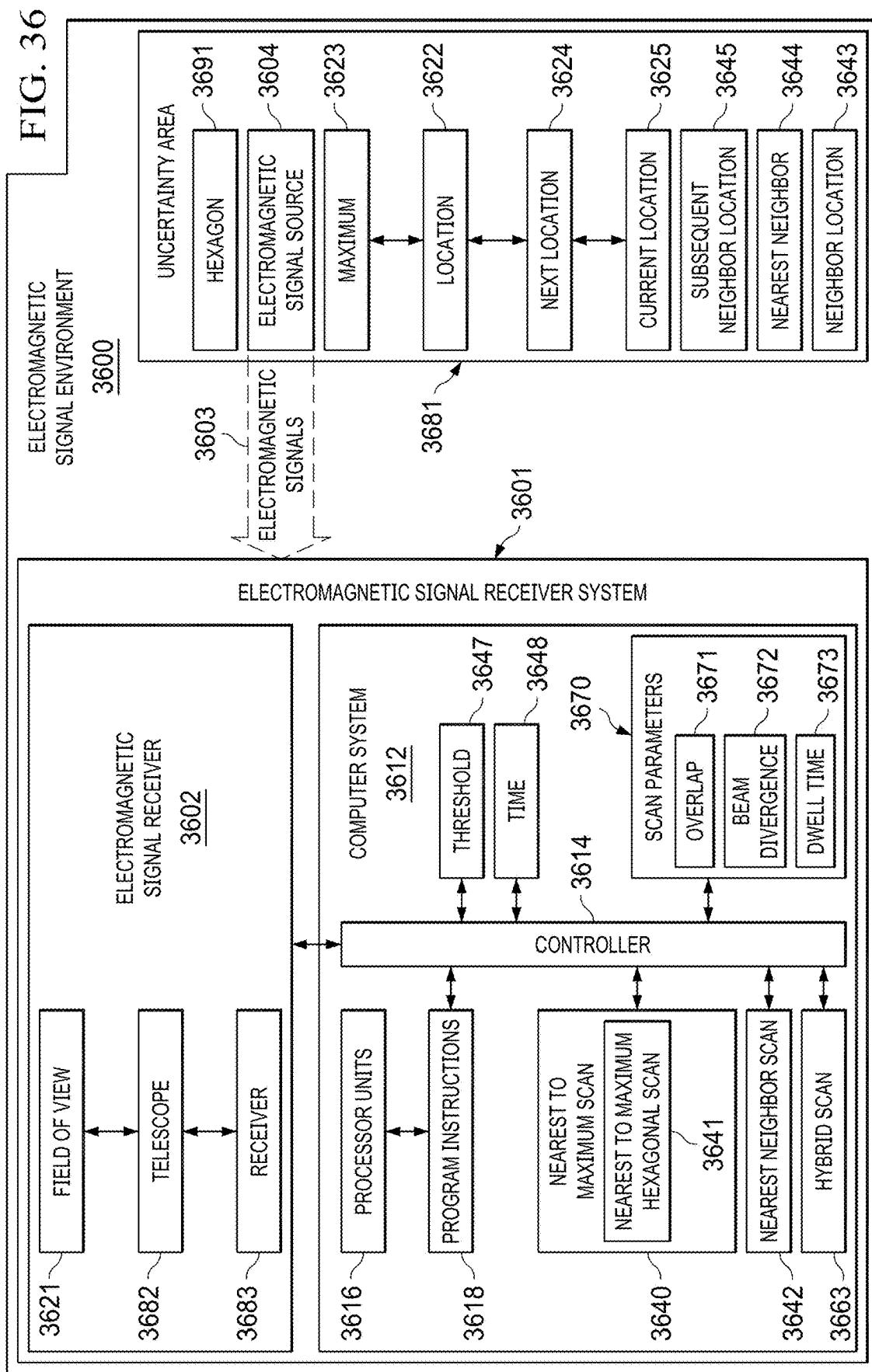


FIG. 34

FIG. 35 ~ 3500





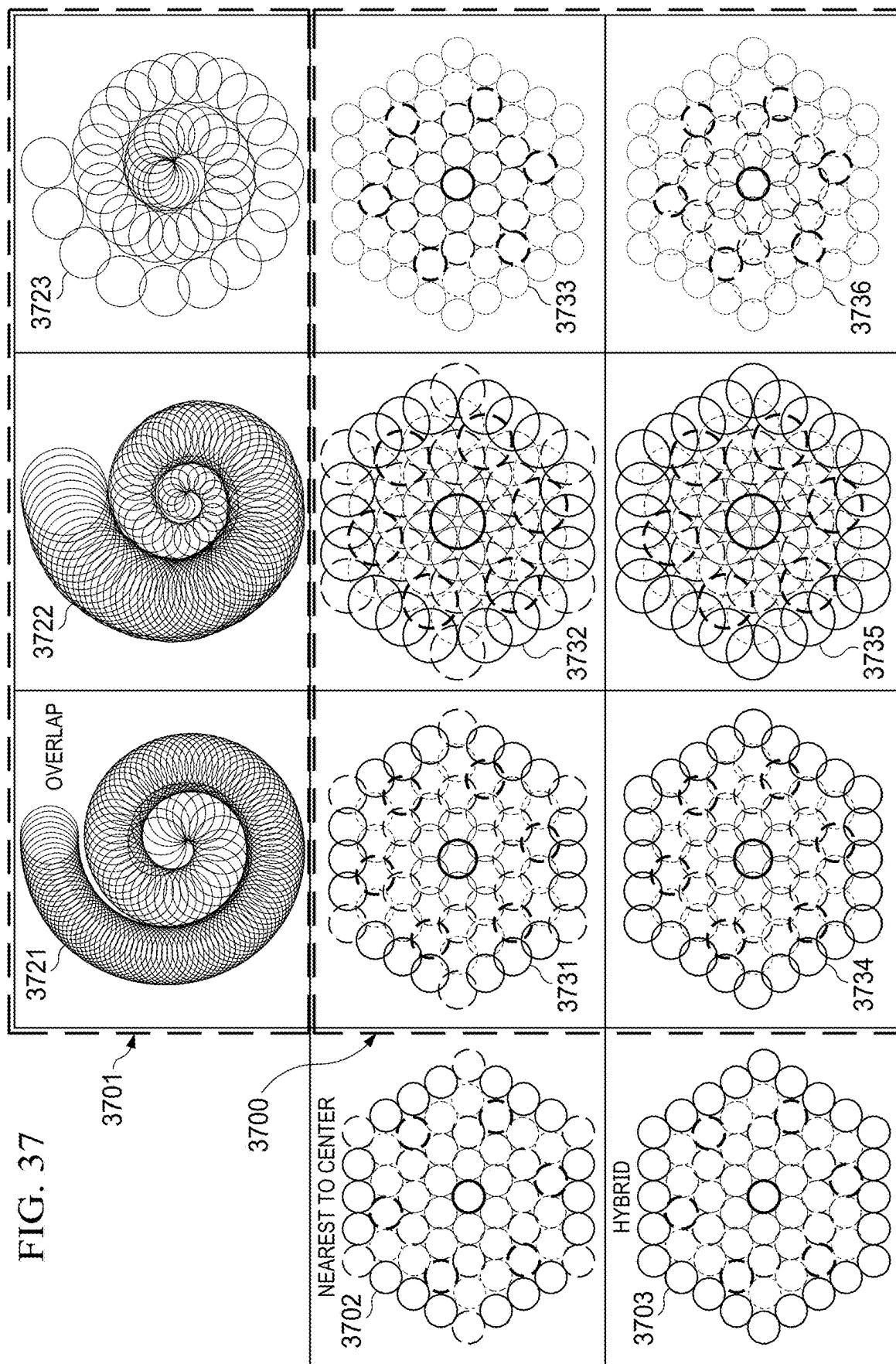


FIG. 37

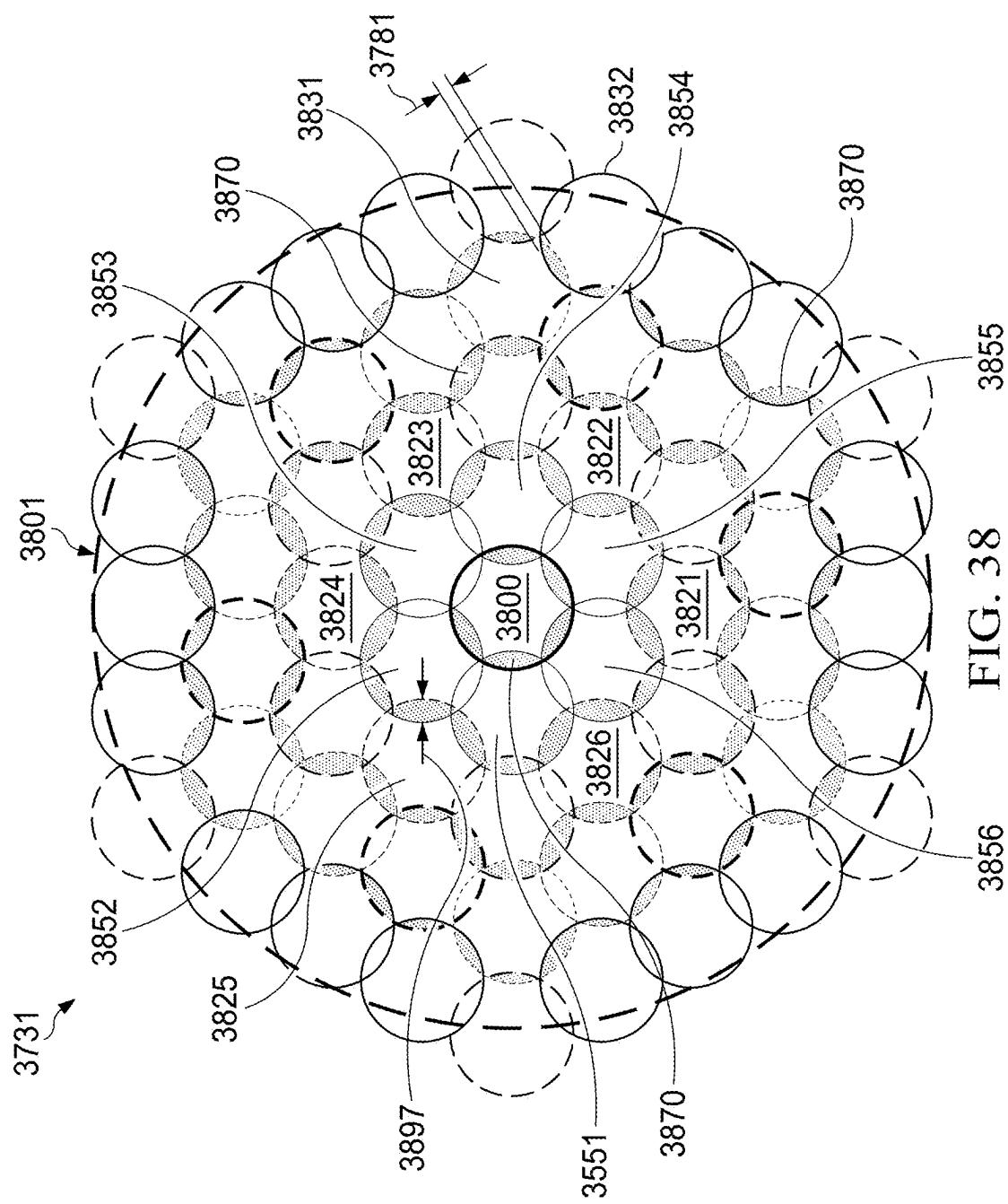


FIG. 38

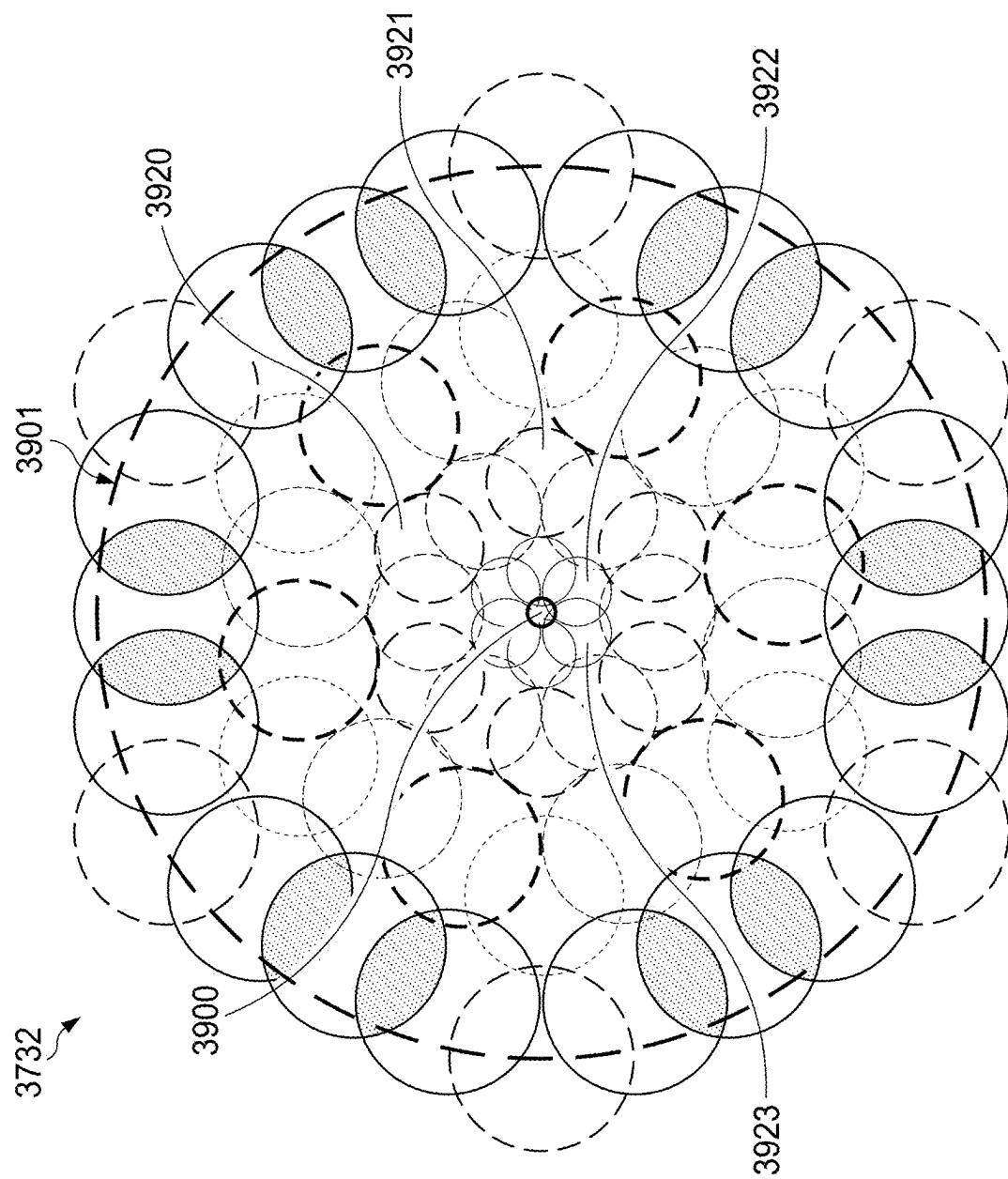


FIG. 39

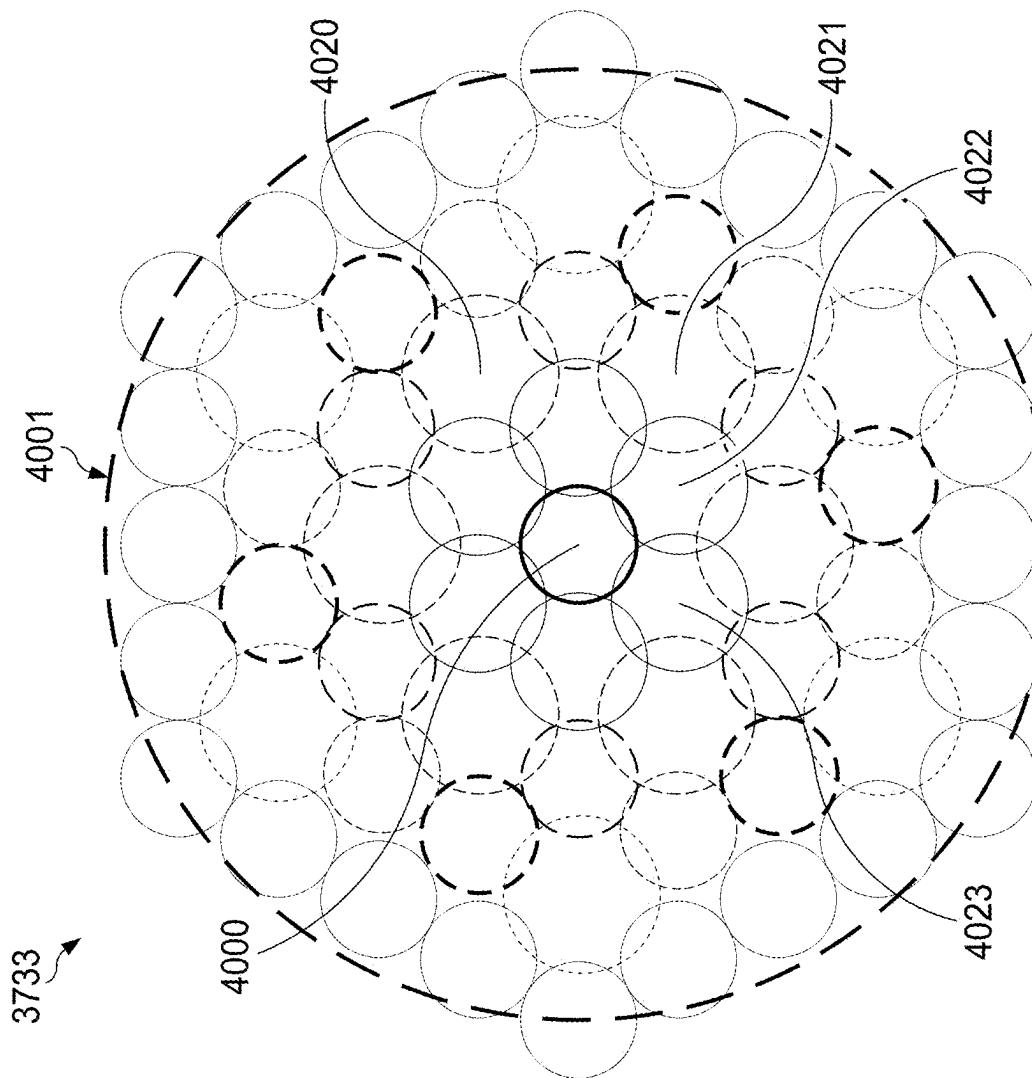


FIG. 40

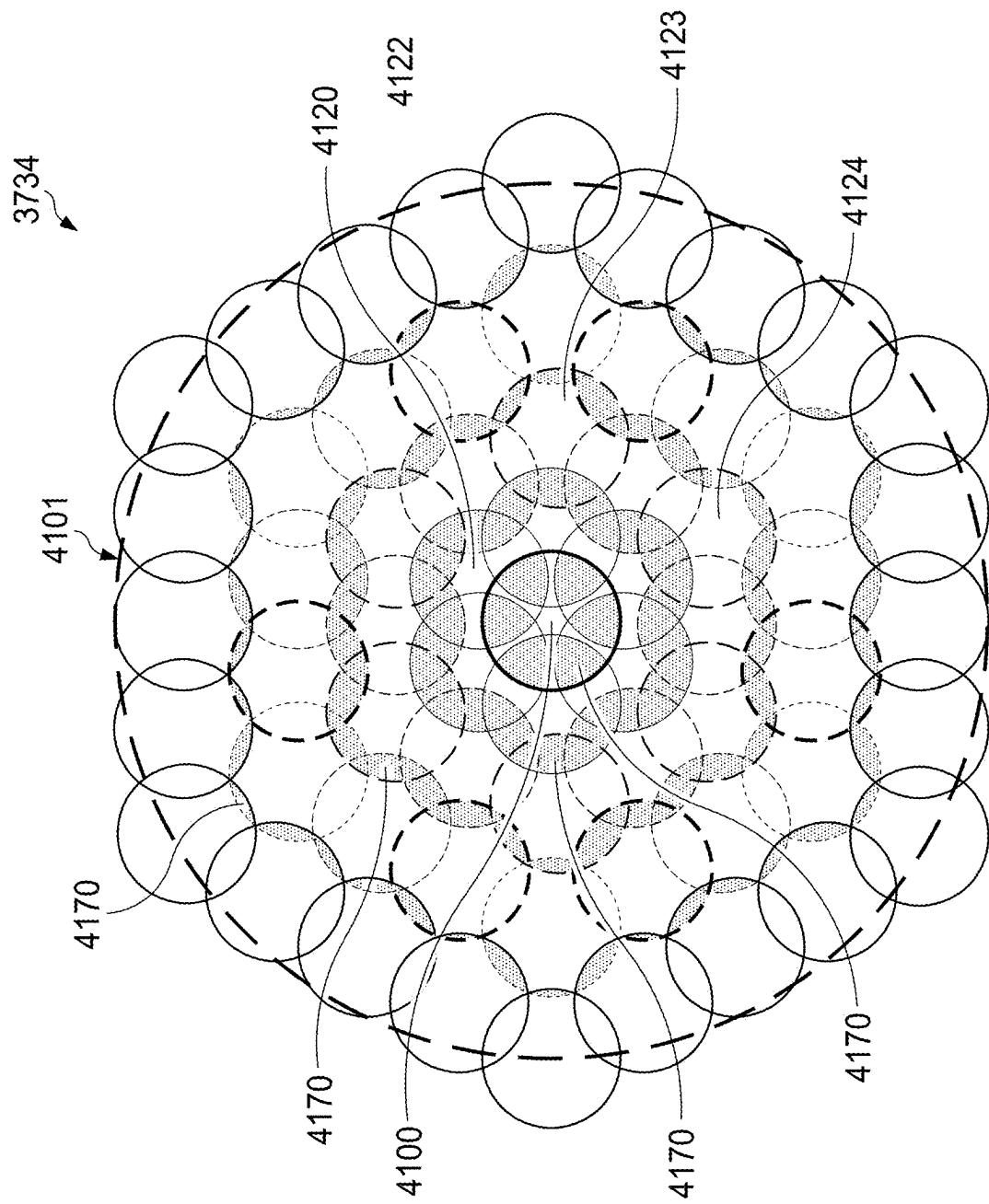
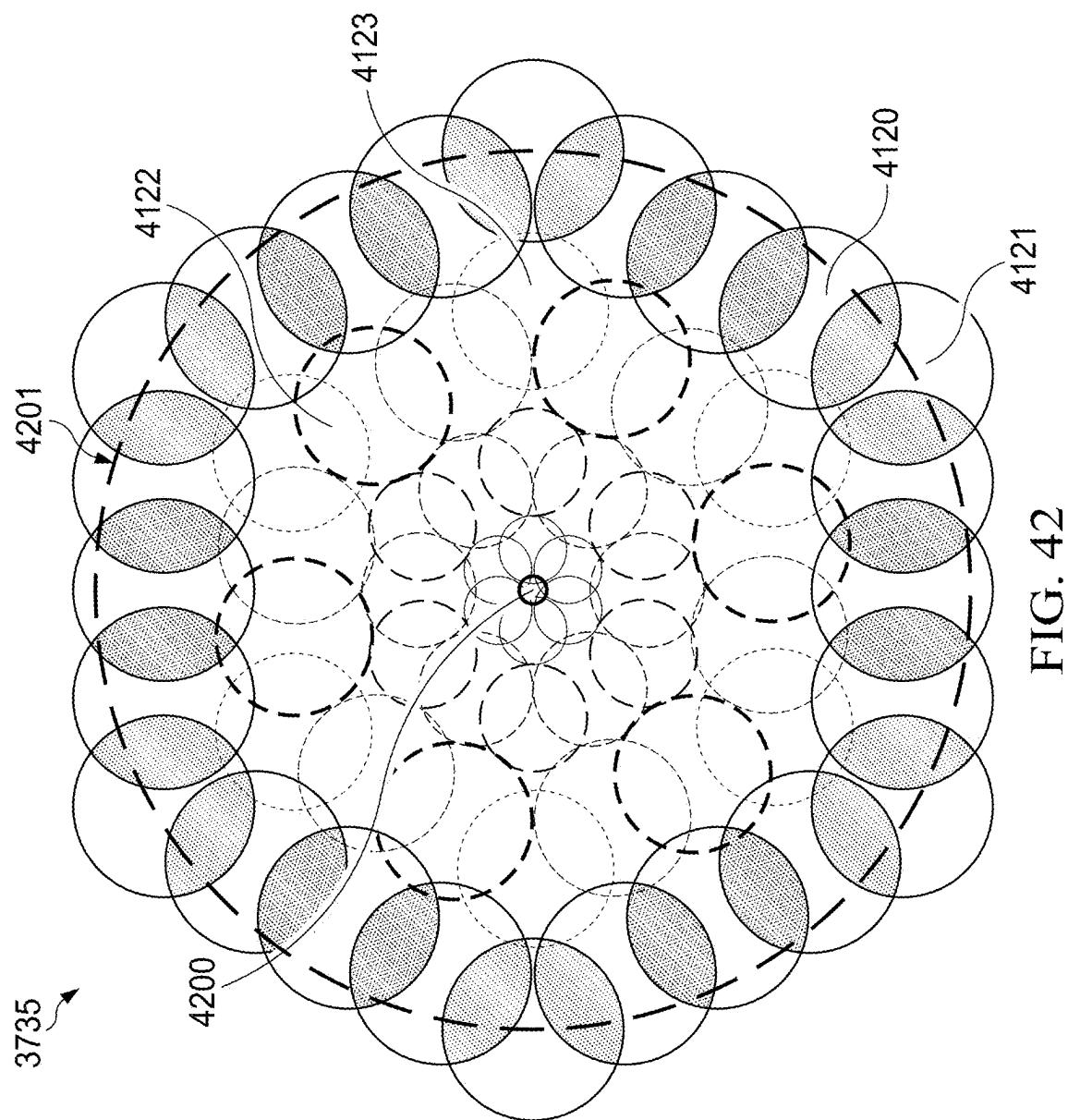


FIG. 41



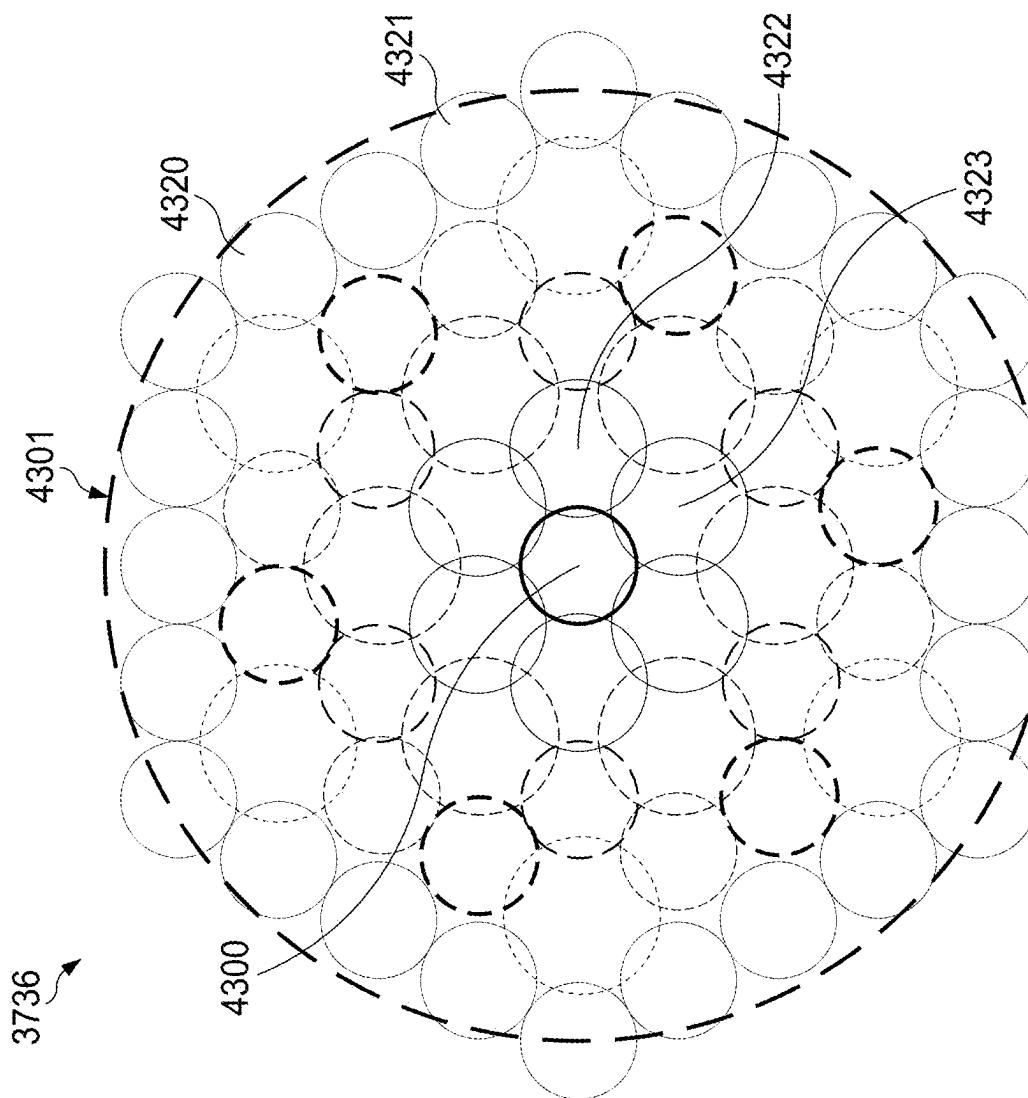


FIG. 43

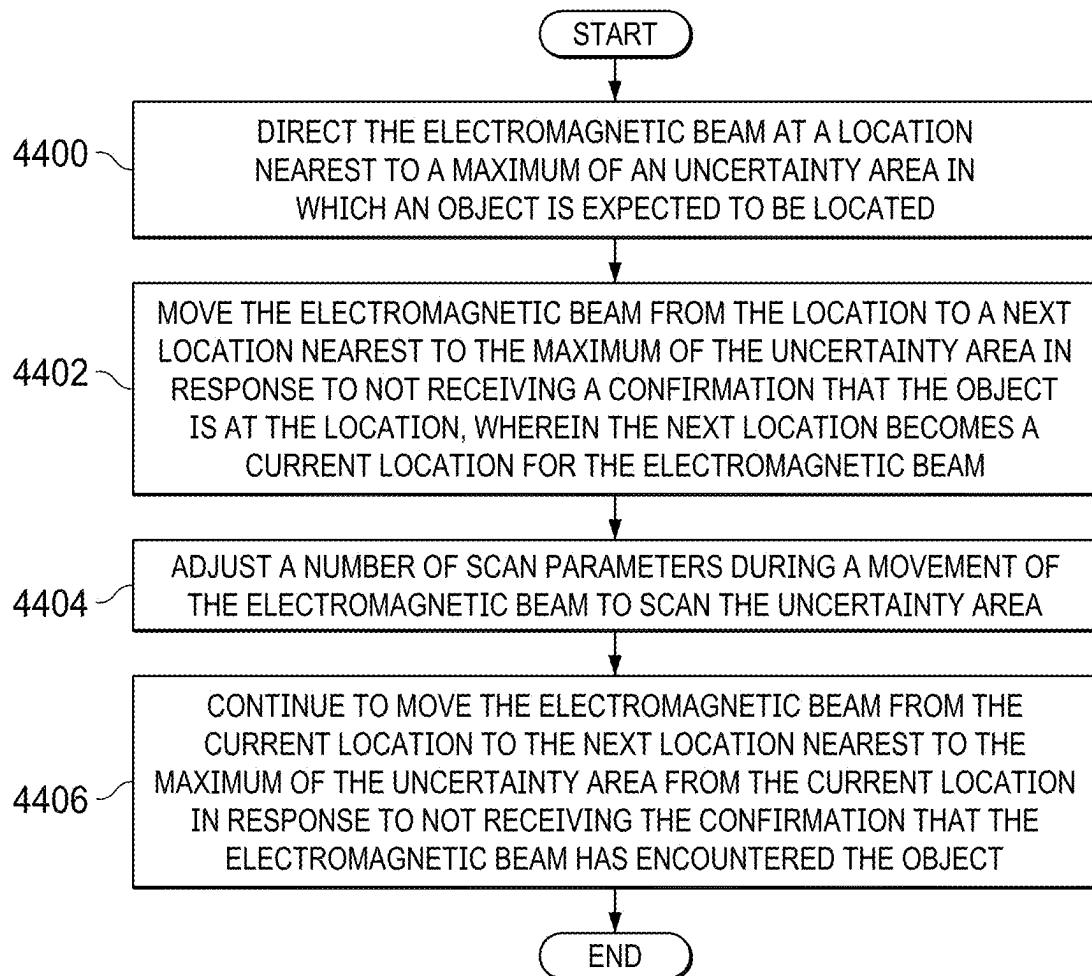


FIG. 44

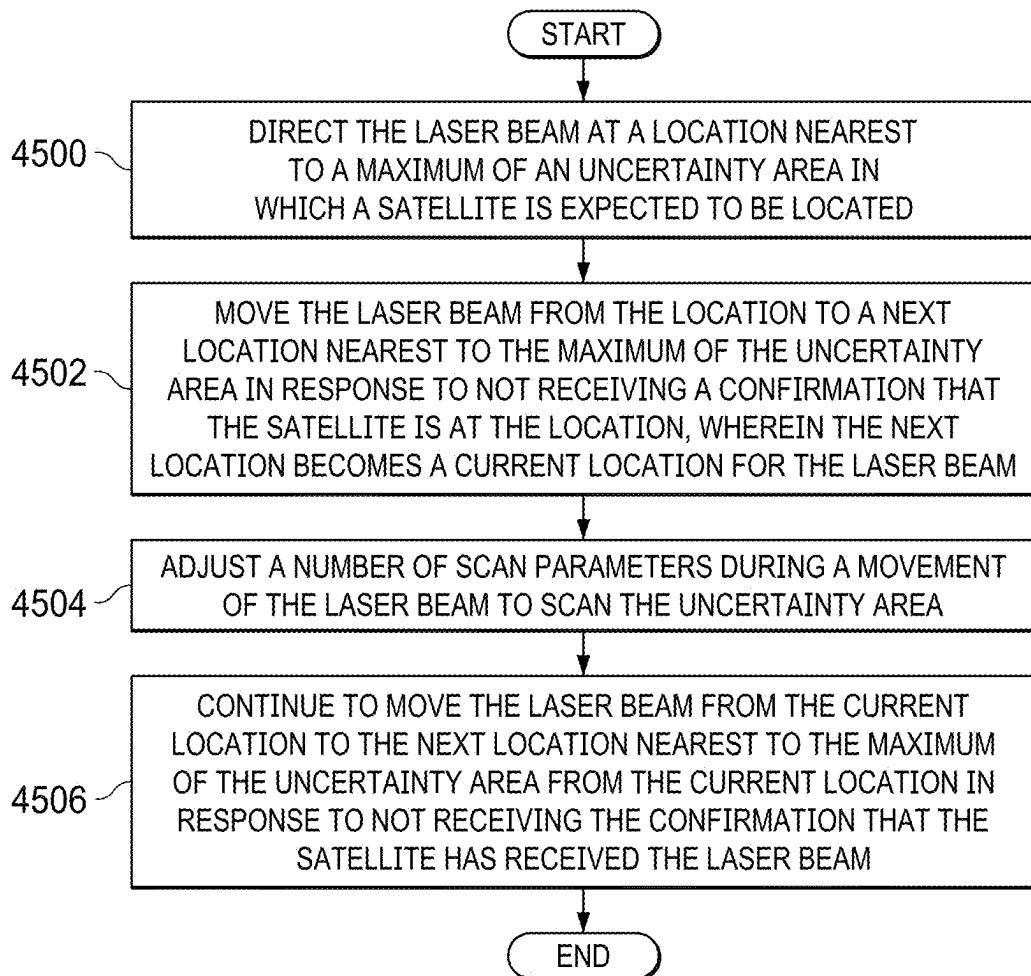


FIG. 45

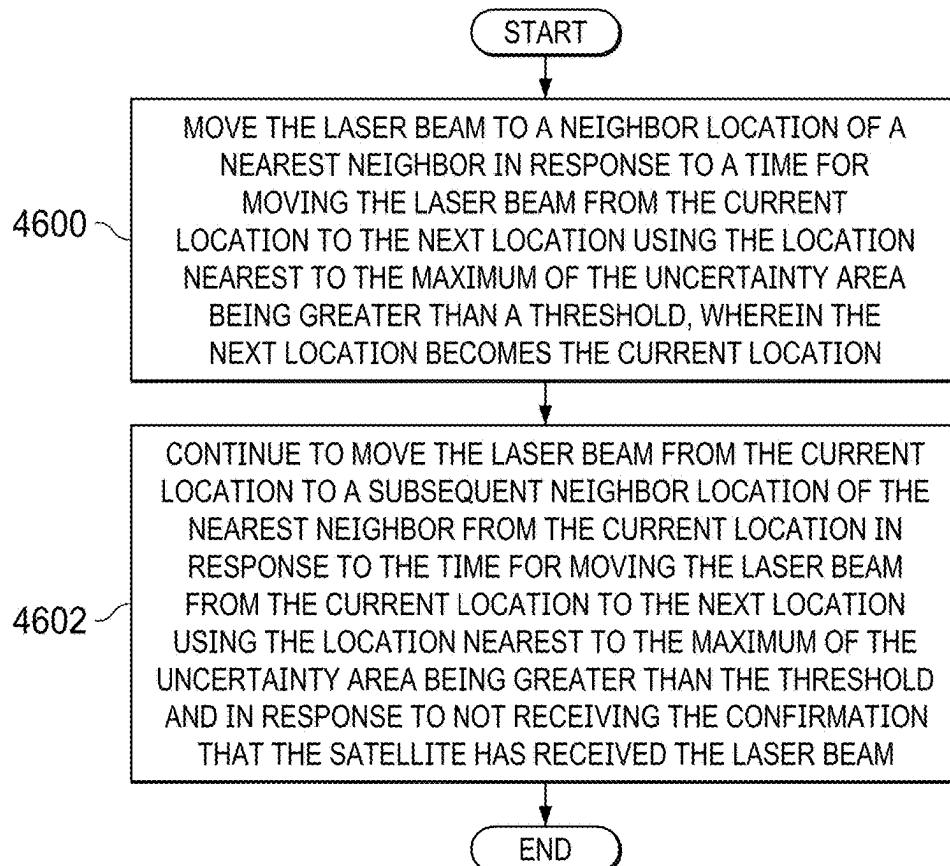


FIG. 46

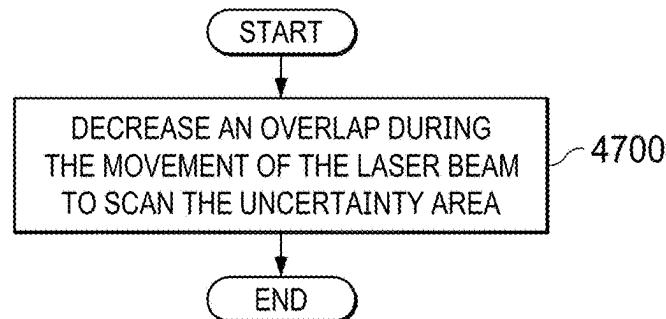


FIG. 47

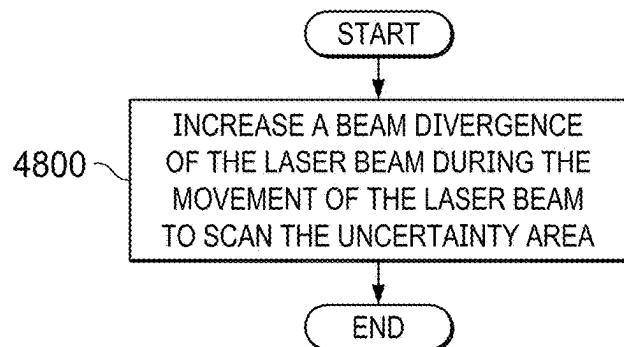


FIG. 48

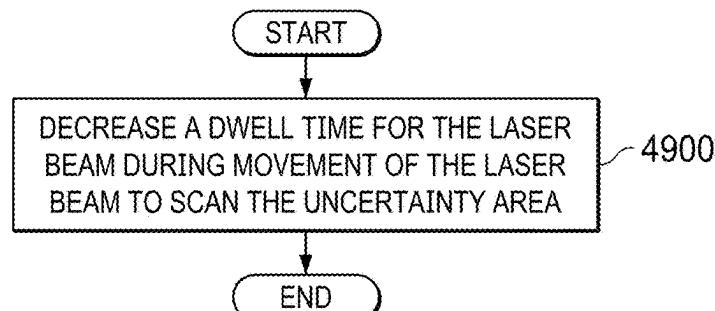


FIG. 49

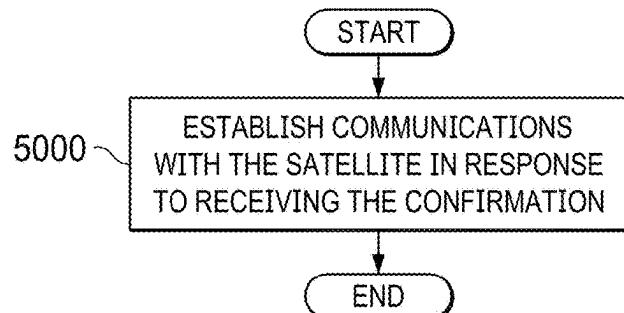


FIG. 50

HONEYCOMB-LIKE LASER BEAM SCAN PATTERN

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a Continuation-In-Part (CIP) and claims the benefit of U.S. patent application Ser. No. 18/442,914, filed Feb. 15, 2024, Attorney Docket No. 23-1025-US-NP, and entitled “Laser Scanning for Spatial Acquisition of a Satellite Receiver,” which is incorporated herein by reference in its entirety.

[0002] This application is related to the following: U.S. patent application entitled “Laser Sensor System With Pattern Scanning,” Ser. No. 18/442,953, attorney docket no. 23-1025-US-NP[2], filed Feb. 15, 2024; U.S. patent application entitled “Laser Beam Based Flight Path Clearing System,” Ser. No. 18/442,984, attorney docket no. 23-1025-US-NP[3], filed Feb. 15, 2024; U.S. patent application entitled “Changing Laser Scan for Satellite Acquisition,” Ser. No. 18/791,572, attorney docket no. 23-1186-US-NP, filed Aug. 1, 2024; U.S. patent application entitled “Variable Scan Parameter Based Laser Sensor System,” Ser. No. 18/791,594, attorney docket no. 23-1186-US-NP[2], filed Aug. 1, 2024; U.S. patent application entitled “Nonuniform Laser Beam Scan Based Flight Path Clearing System,” Ser. No. 18/791,615, attorney docket no. 23-1186-US-NP[3], filed Aug. 1, 2024; and U.S. patent application entitled “Nonlinear Laser Beam Scan Pattern,” Ser. No. _____, attorney docket no. 23-1025-US-CIP [2], filed even date hereof, all of which are assigned to the same assignee and incorporated herein by reference in their entirety.

STATEMENT OF GOVERNMENT SUPPORT

[0003] This invention was made with Government support under DFARS 252.227-7038 awarded by the Department of Defense. The government has certain rights in this invention.

BACKGROUND INFORMATION

1. Field

[0004] The present disclosure relates generally to communications using electromagnetic signals and in particular, to a method, apparatus, and system for directing electromagnetic beam transmitters at receivers and pointing receivers at electromagnetic signal sources.

2. Background

[0005] Satellites can send information to each other using laser beams. With satellite communications, data can be transmitted as laser beams that are encoded with information. The laser beams can carry digital data in the form of on-and-off patterns when laser beam pulses are used. In other cases, the intensity or phase of laser beams can be changed to encode data.

[0006] In establishing satellite communications between two satellites, a laser beam is transmitted from one satellite to another satellite to establish a communications link. Establishing the communications link involves one satellite directing a laser beam at another satellite. This pointing of the laser beam is over great distances and requires precision to properly point the laser beam to establish the communications link.

SUMMARY

[0007] An example of the present disclosure provides a laser beam transmission system comprising a laser beam system and a controller. The laser beam system is configured to transmit a laser beam. The controller is configured to control the laser beam system to direct the laser beam at a central location in a search area in which a satellite is expected to be located and move the laser beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location. The next location becomes a current location for the laser beam. The controller is configured to control the laser beam system to adjust a number of scan parameters during a movement of the laser beam to scan the search area. The controller is configured to control the laser beam system to continue to move the laser beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the satellite has received the laser beam.

[0008] Another example of the present disclosure provides an electromagnetic beam transmission system comprising an electromagnetic beam system and a controller. The electromagnetic beam system is configured to transmit an electromagnetic beam. The controller is configured to control the electromagnetic beam system to direct the electromagnetic beam at a central location in a search area in which an object is expected to be located and move the electromagnetic beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the object is at the central location. The next location becomes a current location for the laser beam. The controller is configured to control the electromagnetic beam system to adjust a number of scan parameters during a movement of the electromagnetic beam to scan the search area. The controller is configured to control the electromagnetic beam system to continue to move the electromagnetic beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the object has received the electromagnetic beam.

[0009] Yet another example of the present disclosure provides a method for pointing a laser beam. The laser beam is directed at a central location in a search area in which a satellite is expected to be located. The laser beam is moved to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location. The next location becomes a current location for the laser beam. A number of scan parameters is adjusted during a movement of the laser beam to scan the search area. The laser beam is continued to be moved from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the object has received the laser beam.

[0010] Still another example of the present disclosure provides an electromagnetic beam receiver system comprising an electromagnetic signal receiver and a controller. The magnetic signal receiver is configured to receive electromagnetic signals. The controller is configured to control the electromagnetic signal receiver to move a field of view of the electromagnetic signal receiver to a central location in a search area in which an electromagnetic signal source is expected to be located and move the field of view to a next

location that is a nearest neighbor to the central location in response to not detecting the electromagnetic signals from the electromagnetic signal source at the central location. The next location becomes a current location for the field of view. The controller is configured to control the electromagnetic signal receiver to adjust a number of scan parameters during a movement of the field of view to scan the search area. The controller is configured to control the electromagnetic signal receiver to continue to move the field of view from the current location to the next location that is the nearest neighbor to the current location in response to not detecting electromagnetic signals from the electromagnetic signal source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0012] FIG. 1 is a pictorial illustration of a satellite communications environment in which illustrative examples may be implemented;

[0013] FIG. 2 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0014] FIG. 3 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0015] FIG. 4 is an illustration of locations for pointing an electromagnetic beam system or an electromagnetic signal receiver in accordance with an illustrative example;

[0016] FIG. 5 is an illustration of locations and beam spots and angles between beam spots in accordance with an illustrative example;

[0017] FIG. 6 is an illustration of a flowchart of a process for identifying locations for scanning an uncertainty area in accordance with an illustrative example;

[0018] FIG. 7 is an illustration of a flowchart of a method for pointing an electromagnetic beam in accordance with an illustrative example;

[0019] FIG. 8 is an illustration of a flowchart of a method for pointing a laser beam in accordance with an illustrative example;

[0020] FIG. 9 is an illustration of a flowchart of a process for continuing to move a laser beam in accordance with an illustrative example;

[0021] FIG. 10 is an illustration of a flowchart of a process for continuing a laser beam in accordance with an illustrative example;

[0022] FIG. 11 is an illustration of a flowchart of a process for moving a laser beam in accordance with an illustrative example;

[0023] FIG. 12 is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0024] FIG. 13 is an illustration of a flowchart of a process for receiving electromagnetic signals in accordance with an illustrative example;

[0025] FIG. 14 is an illustration of a flowchart of a process for continuing to move a field of view in accordance with an illustrative example;

[0026] FIG. 15 is an illustration of a flowchart of a process for continuing to move a field of view in accordance with an illustrative example;

[0027] FIG. 16 is an illustration of a flowchart of an operation for moving a field of view in accordance with an illustrative example;

[0028] FIG. 17 is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0029] FIG. 18 is an illustration of a flowchart of a process for detecting electromagnetic signals in accordance with an illustrative example;

[0030] FIG. 19 is an illustration of a block diagram of a data processing system in accordance with an illustrative example;

[0031] FIG. 20 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0032] FIG. 21 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0033] FIG. 22 is an illustration of hexagonal scans performed using scan parameters that are adjusted during the scanning of a search area in accordance with an illustrative embodiment;

[0034] FIG. 23 is an illustration of a hexagon scan with decreasing overlap in accordance with an illustrative embodiment;

[0035] FIG. 24 is an illustration of a hexagon scan with increasing beam divergence in accordance with an illustrative embodiment;

[0036] FIG. 25 is an illustration of a hexagon scan with decreasing dwell time in accordance with an illustrative embodiment;

[0037] FIG. 26 is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;

[0038] FIG. 27 is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;

[0039] FIG. 28 is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0040] FIG. 29 is an illustration of a flowchart of a process for decreasing overlap in accordance with an illustrative embodiment;

[0041] FIG. 30 is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0042] FIG. 31 is an illustration of a flowchart of a process for increasing beam divergence in accordance with an illustrative embodiment;

[0043] FIG. 32 is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0044] FIG. 33 is an illustration of a flowchart of a process for decreasing dwell time in accordance with an illustrative embodiment;

[0045] FIG. 34 is an illustration of a flowchart of a process for receiving electromagnetic signals in accordance with an illustrative embodiment;

- [0046] FIG. 35 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;
- [0047] FIG. 36 is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;
- [0048] FIG. 37 is an illustration of scans performed using scan parameters that are adjusted during the scanning of an uncertainty area in accordance with an illustrative embodiment;
- [0049] FIG. 38 is an illustration of a nearest to center scan with decreasing overlap in accordance with an illustrative embodiment;
- [0050] FIG. 39 is an illustration of a nearest to center scan with increasing beam divergence in accordance with an illustrative embodiment;
- [0051] FIG. 40 is an illustration of a nearest to center scan with decreasing dwell time in accordance with an illustrative embodiment;
- [0052] FIG. 41 is an illustration of a hybrid scan with decreasing overlap in accordance with an illustrative embodiment;
- [0053] FIG. 42 is an illustration of a hybrid scan with increasing beam divergence in accordance with an illustrative embodiment;
- [0054] FIG. 43 is an illustration of a hybrid scan with decreasing dwell time in accordance with an illustrative embodiment;
- [0055] FIG. 44 is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;
- [0056] FIG. 45 is an illustration of a flowchart of a process for pointing a laser beam in accordance with an illustrative embodiment;
- [0057] FIG. 46 is an illustration of a flowchart of a process for moving the laser beam in accordance with an illustrative embodiment;
- [0058] FIG. 47 is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment;
- [0059] FIG. 48 is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment;
- [0060] FIG. 49 is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment; and
- [0061] FIG. 50 is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

[0062] The illustrative examples recognize and take into account one or more different considerations as described herein. During the initial acquisition in establishing the communications link, a time efficient scanning method for pointing laser beams at satellites is desired. Various scanning methods can be used to point a laser beam from a transmitting satellite to a receiving satellite. In satellite communications, lasers beams can different wavelengths such as, for example, a wavelength of about 1064 nm in the near infrared wavelength range, 1550 nm in the visible wavelength range, and 532 nm in the visible wavelength range. Current laser scanning methods include a continuous spiral scan, a step spiral scan, a segment scan, and a raster scan. These types of

scans for establishing the communications link may not be fast enough to meet various requirements.

[0063] In one illustrative example, rather than simply scanning a laser beam from location to location, the laser beam can be moved between points in a step-like fashion using a pattern that is the most efficient packing density for the area being scanned.

[0064] Further, one illustrative example takes advantage of the Gaussian probability distribution of the satellite location in the area. For example, the laser beam can be moved to a location nearest to the maximum of the uncertainty area using the Gaussian probability distribution. This type of movement can result in skipping locations in the beam pattern in contrast to the current scanning techniques that move the laser beam from one location to another location. This type of movement of the laser beam can be more difficult than moving to neighboring locations.

[0065] For example, a laser beam transmission system comprises a laser beam system configured to transmit a laser beam and a controller. The controller can be configured to control the laser beam transmission system to direct the laser beam at a location nearest to a center of an area in which the satellite is expected to be located. The controller can be configured to control the laser beam transmission system to move the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam. The controller can be configured to control the laser beam transmission system to continue to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the satellite has received the laser beam.

[0066] In another illustrative example, the laser beam changes from moving the laser beam from the current location to the next location nearest to the maximum of the uncertainty area to moving the laser beam to neighboring locations at the cost of not fully taking advantage of the Gaussian distribution of the satellite in the uncertainty area. This type of movement of the laser beam to the nearest neighbor location can be used when moving the laser beam to the next location that is nearest to the maximum of the uncertainty area being scanned takes more time than moving the laser into the neighboring location or is greater than some other threshold. As a result, a hybrid scan can be performed in the illustrative example.

[0067] For example, the controller is configured to control the laser beam system to move the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold. The controller is configured to control the laser beam system to continue to move the laser beam from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not receiving a confirmation that the satellite has received the laser beam.

[0068] With reference now to the figures and, in particular, with reference to FIG. 1, a pictorial illustration of a satellite

communications environment is depicted in which illustrative examples may be implemented. As depicted, satellite communications environment **100** is an environment in which electromagnetic signals can be transmitted for satellite communications.

[0069] For example, satellite **101** transmits laser beam **103** to satellite **102** to establish a communications link with satellite **102**. With the establishment of a communications link, satellite **101** and satellite **102** can communicate information using laser beams. The transmission data using laser beams can be unidirectional from satellite **101** to satellite **102** or from satellite **102** to satellite **101**. In another example, the communication of data using laser beams can be bidirectional between satellite **101** and satellite **102**.

[0070] In this illustrative example, satellite **102** is expected to be located somewhere in area **104**. In this example, area **134** is an area in satellite **134** can be located. This area can be determined based on an estimated location of satellite **134**. This estimate has uncertainty that can also be used to determine area **134**. The uncertainty in the location of a satellite can be a range of possible positions wherein the satellite may be located. For example, the location uncertainty for a satellite is a result of the satellite navigation system's attitude and ephemeris uncertainties (~ hundreds of mrad), which are expressed as azimuth and elevation uncertainties. The probability distribution function for satellite position can be described by a Gaussian distribution for both azimuth and elevation uncertainties.

[0071] In this illustrative example, the laser beam **103** is transmitted at locations in area **104** using a pattern that provides for a faster locating of satellite **102** as compared to current scanning techniques.

[0072] In one illustrative example, satellite **101** transmits laser beam **103** from location **106** to location **108** within area **104**. In this example, selecting location **108** after directing laser beam **103** at location **106** is made by selecting the location that is nearest to maximum **105** of area **104** in which satellite **102** is expected to be located. Location **108** is a location that has not yet been selected for transmitting laser beam **103**. In this illustrative example, the next location is not necessarily the nearest neighbor to location **106**.

[0073] This type of movement of laser beam **103** can continue until satellite **102** is located. In this illustrative example, a confirmation can be received from satellite **102** or some other source that laser beam **103** is directed at satellite **102** in a manner such that communications can be established.

[0074] Additionally, if the amount of time from location **106** to the next location, location **108**, that is nearest to maximum **105** of area **104** is greater than some threshold, then satellite **101** can direct laser beam **103** to the next nearest neighbor from location **106**. In this example, the next nearest neighbor to location **106** is location **109**. This change provides for hybrid scanning that also enables finding the location of satellite **102** within area **104** more quickly as compared to current techniques.

[0075] Further, within satellite communications environment **100**, satellite **120** broadcasts information in electromagnetic signals **121** that can be received by receiver **122**. Electromagnetic signals **121** can be at least one of the electric or magnetic fields that carrier information. At least one of amplitude, frequency, or phase can modulated to encode information in electromagnetic signals **121**. In this

illustrative example, telescope **123** is a component for receiver **122**. As depicted in this example, these components are located on ground **125**.

[0076] Telescope **123** is a physical device that can be used to transmit and receive signals. For example, telescope **123** includes optics and other components that can be used to collect and focus incoming electromagnetic signals such as light waves or radio waves.

[0077] In this illustrative example, satellite **120** is expected to be within area **134**.

[0078] Telescope **123** has field of view (FOV) **124** that can be pointed at different locations in area **134**. In other words, telescope **123** has optics for other components that define field of view **124**.

[0079] Field of view **124** for telescope **123** can be pointed at location **135** in area **134**. The selection of location **135** is based on a location nearest to maximum **141** of area **134**.

[0080] Field of view **124** can be moved from location **135** to location **138** within area **134**. As with transmitting laser beam **103**, the movement of field of view **124** may be to another location if the next location nearest to maximum **141** of area **134** in which satellite **120** is expected to be located. In this example, the next location is location **138**, which is not the nearest neighbor to location **135**.

[0081] This movement of the field of view **124** can continue to occur until receiver **122** detects electromagnetic signals **121** from satellite **120**. In other illustrative examples, this process can be halted when some threshold amount of time occurs without detecting electromagnetic signals **121** or if the entire area is searched without detecting electromagnetic signals **121**. Directional amount of time can be user set in one illustrative example.

[0082] In this illustrative example, electromagnetic signals **121** may be considered to be detected when receiver **122** is able to extract for identifying information within electromagnetic signals **121**. In another example, electromagnetic signals **121** can be considered to be detected when electromagnetic signals above a noise level are detected.

[0083] If the amount of time to move field of view **124** from location **135** to the next location is greater than some threshold, then field of view **124** can be moved to the next nearest neighbor from location **136**, such as location **139**. The next location is location **138** that is nearest to maximum **141** of area **134** in this example. This threshold can be, for example, thematic time to move the field of view from location to a neighboring or adjacent location. This change provides for hybrid scanning that also enables finding the location of satellite **102** within area **104** more quickly as compared to current techniques.

[0084] The illustration of satellite communications environment **100** is provided as one example and is not meant to limit the manner in which other illustrative examples can be implemented. Although the areas are shown as circular, the areas in which the satellites can be located can take other shapes. For example, the areas can be elliptical, hexagonal, or some other shape in the different examples. These areas can also be referred to as uncertainty areas in which a satellite or other object may be located.

[0085] In another illustrative example, laser beam **103** can take another form. For example, a microwave beam can be used in place of laser beam **103**.

[0086] In yet another illustrative example, receiver **122** and telescope **123** can be located in another location other than on ground **125**. For example, receiver **122** and tele-

scope 123 can be located on a platform such as a vehicle, a ship, an aircraft, a building, or some other suitable location.

[0087] With reference now to FIG. 2, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative example. In this illustrative example, electromagnetic signal environment 200 includes components that can be implemented in hardware such as the hardware in satellite 101 and satellite 102 in FIG. 1.

[0088] In this illustrative example, electromagnetic beam transmission system 202 can point the transmission of electromagnetic beam 203 at object 293. In this example, object 293 can be electromagnetic beam receiver 204. Object 293 can also be platform 205 with which electromagnetic beam receiver 204 is connected in this example.

[0089] In this illustrative example, electromagnetic beam transmission system 202 comprises electromagnetic beam system 220 and controller 214. In this example, controller 214 is located in computer system 212. As depicted, computer system 212 is also part of electromagnetic beam transmission system 202.

[0090] Electromagnetic beam system 220 is a physical hardware system. This hardware system is configured to transmit electromagnetic beam 203.

[0091] Controller 214 can be implemented in software, hardware, firmware, or a combination thereof. When software is used, the operations performed by controller 214 can be implemented in program instructions configured to run on hardware, such as a processor unit. When firmware is used, the operations performed by controller 214 can be implemented in program instructions and data can be stored in persistent memory to run on a processor unit. When hardware is employed, the hardware can include circuits that operate to perform the operations in controller 214.

[0092] In the illustrative examples, the hardware can take a form selected from at least one of a circuit system, an integrated circuit, an application-specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device can be configured to perform the number of operations. The device can be reconfigured at a later time or can be permanently configured to perform the number of operations. Programmable logic devices include, for example, a programmable logic array, a programmable array logic, a field-programmable logic array, a field-programmable gate array, and other suitable hardware devices. Additionally, the processes can be implemented in organic components integrated with inorganic components and can be comprised entirely of organic components excluding a human being. For example, the processes can be implemented as circuits in organic semiconductors.

[0093] As used herein, "a number of" when used with reference to items, means one or more items. For example, "a number of operations" is one or more operations.

[0094] Further, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items can be used, and only one of each item in the list may be needed. In other words, "at least one of" means any combination of items and number of items may be used from the list, but not all of the items in the list are required. The item can be a particular object, a thing, or a category.

[0095] For example, without limitation, "at least one of item A, item B, or item C" may include item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combination of these items can be present. In some illustrative examples, "at least one of" can be, for example, without limitation, two of item A; one of item B; and ten of item C; four of item B and seven of item C; or other suitable combinations.

[0096] Computer system 212 is a physical hardware system and includes one or more data processing systems. When more than one data processing system is present in computer system 212, those data processing systems are in communication with each other using a communications medium. The communications medium can be a network. The data processing systems can be selected from at least one of a computer, a server computer, a tablet computer, or some other suitable data processing system.

[0097] As depicted, computer system 212 includes a number of processor units 216 that are capable of executing program instructions 218 implementing processes in the illustrative examples. In other words, program instructions 218 are computer-readable program instructions.

[0098] As used herein, a processor unit in the number of processor units 216 is a hardware device and is comprised of hardware circuits such as those on an integrated circuit that respond to and process instructions and program code that operate a computer. When the number of processor units 216 executes program instructions 218 for a process, the number of processor units 216 can be one or more processor units that are in the same computer or in different computers. In other words, the process can be distributed between processor units 216 on the same or different computers in computer system 212.

[0099] Further, the number of processor units 216 can be of the same type or different types of processor units. For example, the number of processor units 216 can be selected from at least one of a single core processor, a dual-core processor, a multi-processor core, a general-purpose central processing unit (CPU), a graphics processing unit (GPU), a digital signal processor (DSP), or some other type of processor unit.

[0100] In this illustrative example, controller 214 controls electromagnetic beam transmission system 202 to direct electromagnetic beam 203 at location 222 nearest to maximum 223 of uncertainty area 281 in which object 293 is expected to be located. In other words, uncertainty area 281 is an area in which object 293 is thought to be present. However, object 293 may not actually be in uncertainty area 281. In some cases, uncertainty area 281 can be selected as an area for searching with the hope of locating object 293.

[0101] Further in this example, maximum 223 represents a probability that object 293 is at a location (laser spot) covered by laser beam system 230. Maximum 223 does not need to be 100 percent but can be some lower percentage.

[0102] As depicted, electromagnetic beam 203 has beam spot 261. In this example, beam spot 261 is a diameter of electromagnetic beam 203 at a location in uncertainty area 281. In this example, beam spots can correspond to locations in uncertainty area 281. For example, location 222 in uncertainty area 281 can have a size and shape that corresponds to beam spot 261 when the electromagnetic beam 203 is directed at location 222.

[0103] In one illustrative example when object 193 is electromagnetic beam receiver 204, the size of beam spot 261 can affect the ability of electromagnetic beam receiver 204 to detect electromagnetic beam 203. For example, as the spot size of electromagnetic beam 203 increases the divergence of electromagnetic beam 203 increases. This increase results in a faster scan time to point to where electromagnetic beam receiver 204 is located. However, the increase in the size of beam spot 261 can have a divergence in electromagnetic beam 203 that results in an intensity of these signals being too weak for electromagnetic beam receiver 204 to detect.

[0104] In another example, as the size of beam spot 261 decreases, the divergence of electromagnetic beam 203 also decreases. With this lower level divergence, electromagnetic beam receiver 204 can more easily detect electromagnetic beam 203. However, the scan time to locate electromagnetic beam receiver 204 may become slower than desired.

[0105] In another example, the size of beam spot 261 can be set such that the divergence of electromagnetic beam 203 is such that electromagnetic beam 203 can be just barely detected by electromagnetic beam receiver 204. This type of divergence may result in locating electromagnetic beam receiver 204 in a time that is faster than current techniques such as techniques that scan from location to location in which the locations are adjacent to each other.

[0106] Location 222 nearest to maximum 223 of uncertainty area 281 can be determined using a probability density function (PDF) that shows what location is likely to be closest to maximum 223. The probability density function can be used to identify the probability that an object is present in a particular location in an area.

[0107] The probabilities for the location of an object can be generated using the probability density function with the expected location for the object. The probability density function can also be referred to as a type of probability distribution function. The probability density function can be, for example, a Gaussian function, analytical distribution, a skewed distribution, or other type of probability density function.

[0108] For example, the location uncertainty for the receiving satellite is a result of the satellite navigation system's attitude and ephemeris uncertainties (~ hundreds of mrad), which are expressed as azimuth and elevation uncertainties. The probability distribution function for satellite position can be described by a Gaussian distribution for both azimuth and elevation uncertainties using currently known techniques.

[0109] Thus, information can be identified as to the expected location of a satellite based on the satellite orbit information. This expected location may not be the actual location of the satellite. As result, the probabilities that an object is present in different locations within the area of interest can be determined and used for scanning for the object.

[0110] In this example, the area of interest is uncertainty area 281. Maximum 223 is the peak of the probability density function when the probability density function has a single peak.

[0111] In this example, controller 214 controls electromagnetic beam system 220 to move electromagnetic beam 203 from location 222 to next location 224 nearest to maximum 223 of uncertainty area 281 in response to not receiving confirmation 227 that object 293 such as electro-

magnetic beam receiver 204 is at location 222. In this example, next location 224 becomes current location 225 for electromagnetic beam 203.

[0112] Controller 214 controls electromagnetic beam system 220 to continue to move electromagnetic beam 203 from current location 225 to next location 224 nearest to maximum 223 of uncertainty area 281 from current location 225 in response to not receiving a confirmation 227 that electromagnetic beam 203 has encountered object 293, such as electromagnetic beam receiver 204 receiving electromagnetic beam 203. This type of movement of electromagnetic beam 203 is nearest to maximum scan 240.

[0113] In this illustrative example, confirmation 227 can take a number of different forms. For example, confirmation 227 can be a reply or acknowledgment sent in a return electromagnetic beam to electromagnetic beam system 220. In this example, electromagnetic beam system 220 can also receive electromagnetic beams. In another illustrative example, confirmation can be sent through another transmission to controller 214 through another device such as a radiofrequency receiver or other type of receiver.

In one illustrative example, electromagnetic beam 203 can take the form of laser beam 233. Further, laser beam 233 can be selected from a group comprising a continuous laser beam and a pulsed laser beam. Electromagnetic beam system 220 can be laser beam system 230 and platform 205 can take the form of satellite 238.

[0114] In this example, controller 214 controls laser beam system 230 to direct laser beam 233 at location 222 nearest to maximum 223 of uncertainty area 281 in which satellite 238 is expected to be located. Controller 214 also controls laser beam system 230 to move laser beam 233 from location 222 to next location 224 nearest to maximum 223 of uncertainty area 281 in response to not receiving confirmation 227 that satellite 238 is at location 222. In this example, next location 224 becomes current location 225 for laser beam 233. Controller 214 controls laser beam system 230 to continue to move laser beam 233 from current location 225 to next location 224 nearest to maximum 223 of uncertainty area 281 from current location 225 in response to not receiving confirmation 227 that satellite 238 has received laser beam 233. The moving or directing of laser beam 233 can also be referred to as pointing laser beam 233. Further, laser beam 233 can be selected from one of unidirectional communications and bidirectional communications.

[0115] In continuing to move laser beam 233, controller 214 can control laser beam system 232 to move laser beam 233 from current location 225 to next location 224 nearest to maximum 223 of uncertainty area 281 from current location 225 with dwell time 250 at each location in response to not receiving confirmation 227 that satellite 238 has received laser beam 233. In this example, dwell time 250 is the amount of time that laser beam 233 is pointed at a particular location in uncertainty area 281.

[0116] In another illustrative example, in continuing to move laser beam 233, controller 214 can control laser beam system 232 to move laser beam 233 from current location 225 to next location 224 nearest to maximum 223 of uncertainty area 281 from current location 225 with continuous movement 251 from one location to another location in response to not receiving confirmation 227 that satellite 238 has received laser beam 233. In this example, laser beam 233 moves from one location to another location without

pausing or waiting. In other words, dwell time **250** is not present with this type of movement of laser beam **233**.

[0117] In this example, confirmation **227** can be received from satellite **238**. Satellite **238** sends a return laser beam at the same angle as the incoming laser beam **233**.

[0118] In this example, the movement controlled by controller **214** is nearest to maximum scan **240** such as nearest to maximum hexagonal scan **241**. With this example, uncertainty area **281** can be in a shape of hexagon **291**. Further, controller **214** can control the movement of laser beam **233** to change from nearest to maximum scan **240** to nearest neighbor scan **242**. This type of scan in which the scanning changes from nearest to maximum scan **240** to nearest neighbor scan **242** is referred to as hybrid scan **263**.

[0119] For example, controller **214** moves laser beam **233** to neighbor location **243** of nearest neighbor **244** in response to time **248** for moving laser beam **233** from current location **225** to next location **224** using location **222** nearest to maximum **223** of uncertainty area **281** being greater than threshold **247**. In this example, next location **224** becomes current location **225** for future movements.

[0120] In this case, threshold **247** can be selected as the time for moving laser beam **233** from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time. A probability of detection (y-axis) vs. pulse power (x-axis) graph may have two peaks. For low pulse powers (i.e., x values close to zero), an exponentially decreasing curve occurs as pulse power increases. This portion of the curve is caused mostly by noise. At some higher pulse powers, a Gaussian profile occurs in the curve. This portion of the curve is dominated by a signal.

[0121] If the pulse power threshold is set very low (i.e., low values for x), noise is often detected, resulting in a high false alarm rate. If the pulse power threshold is set very high (i.e., high values for x), the signal is almost always detected. Signal pulses can be missed (i.e., probability of detection is very low). However, a pulse power threshold can be selected in between these two extremes that provides a reasonable high probability of detection while having a reasonably low false alarm rate.

[0122] For example, for a single pulse, if a probability of detection of >90% is desired, this probability may require setting a threshold 1.28 standard deviations below the mean (i.e., peak) of the Gaussian curve. If a probability of detection of >99.9% is desired, this probability may set a threshold 3.0 standard deviations below the mean (i.e., peak) of the Gaussian curve. The false alarm rate can depend on factors such as the nature of the noise source, which drives the exact shape and magnitude of the noise PDF curve.

[0123] Further in this example, controller **214** continues to move laser beam **233** from current location **225** to subsequent neighbor location **245** of nearest neighbor **244** from current location **225** in response to time **248** for moving laser beam **233** from current location to next location **224** using location **222** nearest to maximum **223** of uncertainty area **281** being greater than threshold **247** and in response to not receiving confirmation **227** that satellite **238** has received laser beam **233**.

[0124] As a result, controller **214** changes from using nearest to maximum scan **240** to nearest neighbor scan **242**. This type of hybrid scan can provide a faster location of satellite **238** as compared to just using nearest to maximum scan **240**.

[0125] In moving laser beam **233** to neighbor location **243** of nearest neighbor **244** and continuing to move laser beam **233** from current location **225** to subsequent neighbor location **245** of nearest neighbor **244** from current location **225** is part of a nearest neighbor scan **242** selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

[0126] In response to receiving confirmation **227**, controller **214** establishes communications with satellite **238**. The communication is selected from one of unidirectional communications and bidirectional communications.

[0127] In one illustrative example, one or more technical solutions are present that overcome a technical problem with pointing an electromagnetic beam, such as a laser, at a receiver. As a result, one or more illustrative examples enable pointing a laser beam at a receiver in an efficient manner. The pointing of the laser beam is performed in a manner that uses a nearest to maximum scan as opposed to a nearest neighbor scan.

[0128] Computer system **212** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware, or a combination thereof. As a result, computer system **212** operates as a special purpose computer system in which controller **214** in computer system **212** enables pointing an electromagnetic beam **203** at electromagnetic beam receiver **204** more quickly as compared to current techniques. Controller **214** transforms computer system **212** into a special purpose computer system as compared to currently available general computer systems that do not have controller **214**.

[0129] In the illustrative example, the use of controller **214** in computer system **212** integrates processes into a practical application for pointing electromagnetic beam **203** at electromagnetic beam receiver **204**. In these different examples, the processes identify locations to point electromagnetic beam **203** and control electromagnetic beam transmission system **202** to point electromagnetic beam **203** at the different locations as part of a process to locate electromagnetic beam receiver **204**.

[0130] The illustration of electromagnetic signal environment **200** in FIG. 2 is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0131] For example, electromagnetic beam **203** has been described as being laser beam **233**. Electromagnetic beam **203** can take other forms in other illustrative examples. For example, electromagnetic beam **203** can be selected from a group comprising laser beam **233**, a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam.

[0132] As another example, platform **205** can take a number of different forms in addition to satellite **238**. For example, electromagnetic beam receiver **204** can be located in platform **205** selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt

wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0133] As another example, uncertainty area **281** can take other shapes in addition to hexagon **291**. For example, uncertainty area **281** can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape. Controller **214** can control one or more electromagnetic beam systems in addition to or in place of electromagnetic beam system **220**. Further, the system can be used with an electromagnetic signal receiver system as described below with respect to FIG. 3.

[0134] In another example, controller **214** in electromagnetic beam transmission system **202** can point electromagnetic beam **203** to different locations in an uncertainty area using other mechanisms other than the location nearest to a maximum of an uncertainty area.

[0135] For example, controller **214** can control the electromagnetic beam system **220** to direct electromagnetic beam **203** to a location in uncertainty area **131** using a scan metric. Uncertainty area **281** is an area in which object **293** is expected to be located although it is possible that object **293** may not be in uncertainty area **281**.

[0136] Controller **214** can control electromagnetic beam system **220** to move electromagnetic beam **203** from location **222** to next location **224** using the scan metric in response to not receiving confirmation **227** that object **293** is at location **222**. Next location **224** becomes current location **225** for electromagnetic beam **203**. Controller **214** can control electromagnetic beam system **220** to continue to move the electromagnetic beam **203** from current location **225** to next location **224** using the scan metric in response to not receiving confirmation **227** that object **293** is at location **222**.

[0137] Further in this example, controller **214** selects next location **224** in uncertainty area **281** from a set of candidate locations that has a highest value for the scan metric, wherein the scan metric is as follows:

$$M = \text{PDF}_{int}/t_{tot}$$

[0138] where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time $t_{tot}=t_{slew}+t_{dwell}$, t_{slew} is a time to slew a line-of-sight from a current location to the next potential location, and t_{dwell} is a time the line of site dwells at the next potential location.

[0139] Pointing electromagnetic signal receiver at an electromagnetic signal source also takes more time than desired and is more challenging than desired. With reference now to FIG. 3, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative example. In this illustrative example, electromagnetic signal environment **300** includes components that can be implemented in hardware such as the hardware shown in satellite **120** and receiver **122** and telescope **123** in FIG. 1.

[0140] In the illustrative example, electromagnetic signal receiver system **301** in electromagnetic signal environment **300** can be pointed to receive electromagnetic signals **303** from electromagnetic signal source **304**. In this example, electromagnetic signal receiver system **301** comprises electromagnetic signal receiver **302** and controller **314**. In this example, controller **314** is located in computer system **312**. As depicted, computer system **312** is part of electromagnetic signal receiver system **301** in this example.

[0141] In this illustrative example, electromagnetic signal source **304** generates electromagnetic signals **303**. Electromagnetic signals **303** can take a number of different forms. For example, electromagnetic signals **303** can be in a beam, collimated beam, omnidirectional signals, directional signals, or other types of radiation patterns for forms. Electromagnetic signals **303** can be selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, ultraviolet light signals, or other types of electromagnetic signals.

[0142] Electromagnetic signal source **304** can take a number of different forms. For example, electromagnetic signal source **304** can be a platform selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing vehicle, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[0143] Electromagnetic signal receiver **302** is a physical hardware system that can receive electromagnetic signals **303**. Electromagnetic signal receiver **302** has field of view **321**. In this illustrative example, hardware such as an antenna, radio receiver, photo detector, or other device that can detect electromagnetic signals **303** that are in field of view **321**. This hardware is unable to detect or use electromagnetic signals **303** outside the field of view **321**. The hardware can include receiver **383**. Receiver **383** can be implemented using a receiver such as a photodetector, a photodiode system, a phase array antenna, focal plane array (FPA), cell (QC), or other suitable types of hardware.

[0144] In another illustrative example, electromagnetic signal receiver **302** can include telescope **382**. Telescope **382** is a hardware component collecting incoming electromagnetic signals onto a detector in receiver **383**.

[0145] In this illustrative example, field of view (FOV) **321** is the view that electromagnetic signal receiver **302** has to see or receive electromagnetic signals **303**. Field of view **321** may be described as the angular range within which electromagnetic signal receiver **302** can detect or receive electromagnetic signals **303**. In this example, field of view **321** can be defined by telescope **382**.

[0146] In this example, field of view **321** can also be described as the instantaneous angle subtended by the scanning system that exceeds the detection threshold (e.g., the divergence angle of the laser beam (above threshold) for a laser-scanning system, or the sensor field of view for a receiving sensor).

[0147] In some illustrative examples, the size of field of view **321** can be controlled. Field of view **321** should have

a size that enables detecting electromagnetic signals 303. For example, the time for nearest to maximum scan 340 to locate electromagnetic signal source 304 is faster than current techniques such as those that use a continuous file scan a segment scan or raster scan. However, actually detecting electromagnetic signals 303 may be difficult with electromagnetic signals 303 being too weak for detection with the size of field of view 321. For example, the aperture or coping defining the field of view for a receiver may pick up signals from other sources for noises in addition to the signals from the desired source. As result, the receiver may struggle to identify and isolate electromagnetic signals 303 from the surrounding noise. As result, reducing or narrowing field of view 321 be performed to reduce issues with noise. In other words, size of field of view 321 can be adjusted to increase the signal-to-noise ratio.

[0148] In another example, the scan time becomes slower as field of view 321 is decreased. At some point, field of view 321 may be able to easily detect electromagnetic signals 303. However, the amount of scan time may be much slower than desired and may be slower than current techniques.

[0149] The size of field of view 321 can be selected such that electromagnetic signals 303 can be just barely detectable. In other words, these electromagnetic signals can be detected over noise that may be present. With this size for field of view 321, nearest to maximum scan 340 can be performed within a desired amount of time such as less than techniques that use a continuous scan based on a nearest neighbor.

[0150] Controller 314 can be implemented in the same manner as controller 214 in FIG. 2 in which program instructions 318 can be used to implement controller 214 that are executed by a number of processor units 316 in computer system 312. Program instructions 318, the number of processor units 316, and computer system 312 can be implemented in a manner similar to program instructions 218, processor units 216, and the computer system 212 in FIG. 2.

[0151] Controller 314 is configured to control the operation of electromagnetic signal receiver 302. In this illustrative example, controller 314 controls electromagnetic signal receiver 302 to move field of view 321 of electromagnetic signal receiver 302 to location 322 nearest to maximum 323 of uncertainty area 381 in which an electromagnetic signal source 304 is expected to be located. This moving of field of view 321 can also be referred to as pointing field of view 321.

[0152] Further, in this example, controller 314 moves field of view 321 of electromagnetic signal receiver 302 from location 322 to next location 324 nearest to maximum 323 of uncertainty area 381 in response to not detecting electromagnetic signals 303 from electromagnetic signal source 304 at location 322. In this example, next location 324 becomes current location 325 for field of view 321.

[0153] Controller 314 continues to move field of view 321 from current location 325 to next location 324 nearest to maximum 323 of uncertainty area 381 from current location 325 in response to not detecting electromagnetic signals 303 from electromagnetic signal source 304. This type of movement of the field of view 321 is a nearest to maximum scan 340. This scan can be nearest to maximum hexagonal scan 341 with uncertainty area 381. In this example, uncertainty area 381 can be in a shape of hexagon 391. In other

examples, uncertainty area 381 can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape in addition to or in place of hexagon 391.

[0154] Also in this illustrative example, controller 314 can continue to move field of view 321 from current location 325 to next location 324 nearest to maximum 323 of uncertainty area 381 from current location 325 with dwell time 350 at each location in response to not detecting the electromagnetic signals 303 from electromagnetic signal source 304. In other words, including field of view 321 from one location to another location, field of view 321 may remain or stay at one location for a period of time or move to another location.

[0155] In yet another example, controller 314 continues to move field of view 321 from current location 325 to next location 324 nearest to maximum 323 of uncertainty area 381 from current location 325 with continuous movement 351 from one location to another location in response to not detecting electromagnetic signals 303 from electromagnetic signal source 304. In this example, field of view 321 moves to different locations without stopping or pausing at the different locations.

[0156] Further, controller 314 can change the manner in which field of view 321 is moved. In this example, controller 314 can begin with nearest to maximum scan 340 and change to nearest neighbor scan 342. This type of scan in which the scanning changes from nearest to maximum scan 340 to nearest neighbor scan 342 is referred to as hybrid scan 363.

[0157] For example, controller 314 moves field of view 321 to neighbor location 343 of nearest neighbor 344 in response to time 348 for moving field of view 321 from current location 325 to next location 324 using location 322 nearest to maximum 323 of uncertainty area 381 being greater than threshold 347. In this example, next location 324 becomes current location 325.

[0158] Controller 314 continues to move field of view 321 from current location 325 to subsequent neighbor location reported by nearest neighbor 344 from current location 325 in response to time 348 for moving field of view 321 from current location 325 to next location 324 using location 322 nearest to maximum 323 of uncertainty area 381 being greater than threshold 347 and in response to not detecting electromagnetic signals 303 from electromagnetic signal source 304.

[0159] In this case, threshold 347 can be selected as the time for moving field of view 321 from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time.

[0160] Also, moving field of view 321 to neighbor location 343 of nearest neighbor 344 and continuing to move field of view 321 from current location 325 to subsequent neighbor location 345 of nearest neighbor 344 from current location 325 can be part of nearest neighbor scan 342. This nearest neighbor scan can be selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

[0161] In this illustrative example, controller 314 can detect electromagnetic signals 303 from electromagnetic signal source 304 in response to detecting selected electromagnetic signals that are greater than a noise level in field of view 321. In response to detecting electromagnetic signals 303, controller 314 can establish communications with electromagnetic signal source 304. The communications are

selected from one of unidirectional communications and bidirectional communications. In the illustrative example, the communications that are unidirectional from electromagnetic signal source **304** to electromagnetic signal receiver **302** does not necessarily require electromagnetic signal source **304** to know that electromagnetic signals **303** are being received by electromagnetic signal receiver **302**. [0162] The illustration of electromagnetic signal environment **300** in FIG. 3 is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0163] For example, electromagnetic signal receiver system **301** can be located on a platform. The platform can be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0164] In another illustrative example, controller **314** can be located in a separate platform or location from electromagnetic signal receiver system **301**. Additionally, electromagnetic signal receiver system **301** may be used with an electromagnetic signal transmission system such as electromagnetic beam transmission system **202**. In this example, a single controller can be present that controls both systems and that controller can be in a separate location from the systems.

[0165] In yet another illustrative example, controller **314** can be controlled by one or more electromagnetic signal receiver systems in addition to or in place of electromagnetic signal receiver system **301**.

[0166] In one illustrative example, controller **314** in electromagnetic signal receiver system **301** is configured to control electromagnetic signal receiver **302** to move field of view **321** of electromagnetic signal receiver **302** to location **322** in uncertainty area **381** using a scan metric. Uncertainty area **381** is an area in which an electromagnetic signal source **304** is expected to be located. Controller **314** is configured to control electromagnetic signal receiver **302** to move field of view **321** from location **322** to next location **324** using the scan metric in response to not detecting electromagnetic signals **303** from electromagnetic signal source **304** at location **322**. Next location **324** becomes current location **325** for field of view **321**. Controller **314** is configured to control electromagnetic signal receiver **302** to continue to move field of view **321** from current location **325** to next location **324** using the scan metric in response to not detecting electromagnetic signals **303** from electromagnetic signal source **304**.

[0167] Further, controller **314** can select next location **324** in uncertainty area **381** from a set of candidate locations that has a highest value for the scan metric. The scan metric is as follows:

$$M = \text{PDF}_{int} t / t_{tot}$$

where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time $t_{tot}=t_{slew}+t_{dwell}$, t_{slew} is a time to slew a line-of-sight from a current location to the next potential location, and t_{dwell} is a time the line of site dwells at the next potential location.

[0168] With reference now to FIG. 4, an illustration of locations for pointing an electromagnetic beam system or an electromagnetic signal receiver is depicted in accordance with an illustrative example. In this example, locations are depicted within area **400**. This area is an example of an implementation for uncertainty area **281** in FIG. 2 and uncertainty area **381** in FIG. 3. As depicted, area **400** has a hexagonal shape.

[0169] In this example, an electromagnetic beam receiver for an electromagnetic signal source is expected to be within area **400**. In this example, locations can be selected to be the nearest to maximum of uncertainty area **400**. In this example, the maximum of uncertainty area **400** is center **402**. In other illustrative examples, the maximum uncertainty area **400** can be in other locations other than center **402**.

[0170] For example, the first location can be locations for center **402**. The next locations closest to center **402** are locations A.

[0171] Locations selected that are closest to center **402** after locations A are locations B. The next locations used for pointing electromagnetic beams or field of views are locations C. The next locations closest to center **402** are locations D with locations E being the next locations closest to the center after locations D. The next locations closest to center **402** are locations F followed by locations G.

[0172] As can be seen, this type of selection of locations is not a nearest neighbor selection as currently used. In some cases, moving from one location to another location may take more time than using a nearest neighbor selection location. In this case, the process can change from using the nearest to maximum scan of locations to a nearest neighbor scan for locations. A threshold time for changing the type of scan can be selected based on a number of different considerations. This type of scan is a hybrid scan in these different illustrative examples.

[0173] Turning to FIG. 5, an illustration of locations and for beam spots and angles between beam spots is depicted in accordance with an illustrative example. In this example, a scan for directing an electromagnetic beam at beam spots **500** in a pattern can be performed using a nearest to maximum scan. The pattern includes the location of beam spots as well as an order in which an electromagnetic beam is directed to the different beam spots. This pattern can also be referred to as a beam spot pattern. This type of scan can be used to find a location of an electromagnetic beam receiver more quickly as compared to current scanning techniques.

[0174] As depicted, angle Θ_{cc} is between beam spot E and beam spot G, and angle Θ_{nn} is between beam spot E and beam spot F. Also shown is angle φ_{cc} between the center and beam spot G, and angle φ_{nn} is between the center and beam spot F. These angles can be used in determining a pattern of beam spots for pointing an electromagnetic beam.

[0175] In this example, the beam spot pattern can be determined using a nearest to maximum scan. For a given beam spot pattern, the following equation can be used:

$$t_{net\ savings} \approx \frac{t_{scan}}{N} [PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{\text{slew rate}} \quad \text{Equation A}$$

where $t_{net\ savings}$ is the time saved for a single jump from beam spot to beam spot using the nearest to maximum scan relative to the nearest neighbor scan. In other words, this variable is the time it takes for a single jump from one beam spot to another beam spot using the nearest to maximum scan approach minus the time it takes for a single jump from beam spot to beam spot using the nearest neighbor scan to determine the beam spot pattern.

[0176] t_{scan} is the total scan time to use the nearest neighbor scan.

[0177] N is the total number of beam spots in the scan pattern.

[0178] $PDF(\varphi_{cc})$ is a unitless value of the probability density function for the beam spot that was moved to for the nearest to maximum scan. This value is a function of distance from the beam spot to the center of the probability density function, which is equivalent to an angle defined as “ φ ”.

[0179] $PDF(\varphi_{nn})$ is the unitless value of the probability density function for the beam spot that was moved to for the nearest neighbor scan.

[0180] θ_{cc} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest to maximum scan. The units can be degrees or radians.

[0181] θ_{nn} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest neighbor scan.

[0182] slew rate is the speed at which the gimble moves. The units are angular change over time (e.g., degree/s or rad/s).

Example 1

[0183] In this example, the slew rate is infinite. This infinite slew rate means the electromagnetic beam instantly jumps from beam spot to beam spot. In this case Equation A becomes:

$$t_{net\ savings} \approx \frac{t_{scan}}{N} [PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{\infty} = \frac{t_{scan}}{N} [PDF(\varphi_{cc}) - PDF(\varphi_{nn})]$$

[0184] Since $PDF(\varphi_{cc}) \geq PDF(\varphi_{nn})$, $t_{net\ savings} \geq 0$, there is never a need to switch from the closest to center scan to the nearest neighbor scan for determining the beam spot pattern.

Example 2

[0185] In this example, the slew rate can be considered zero resulting in the following:

$$t_{net\ savings} \approx \frac{t_{scan}}{N} [PDF(\varphi_{cc}) - PDF(\varphi_{nn})] - \frac{\theta_{cc} - \theta_{nn}}{0} = -\infty$$

[0186] In this case, the nearest to maximum scan is not needed because the $t_{net\ savings} < 0$.

Example 3

[0187] Example 1 showed that if the slew rate is sufficiently fast, it always saves time to use the nearest to maximum scan to determine a beam spot pattern. Example 2 shows that if the slew rate is sufficiently slow, no time savings is present. In this example, the nearest neighbor scan is used.

[0188] If the slew rate is something in between these extremes, initially, time savings are present using the nearest to maximum scan. When the time savings change from a positive savings to a negative savings, a switch to the nearest neighbor scan can be used.

[0189] Turning next to FIG. 6, an illustration of a flowchart of a process for identifying locations for scanning an uncertainty area is depicted in accordance with an illustrative example. The process in FIG. 6 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. This process can be implemented to identify locations for pointing an electromagnetic beam emitted from magnetic beam transmission system from and for pointing a field of view or an electromagnetic signal receiver. For example, the process can be implemented in controller 214 in computer system 212 in electromagnetic beam transmission system 202 in FIG. 2 and in controller 314 in computer system 312 in electromagnetic signal receiver system 301 in FIG. 3.

[0190] In this example, the pointing involves moving or directing electromagnetic beam 203 in FIG. 2 or field of view 321 in FIG. 3.

[0191] In this example, the field of view can be pointed at an uncertainty area. This uncertainty area is an example of uncertainty area 381 in FIG. 3. This uncertainty area can also be referred to as a field of regard (FOR).

[0192] The process begins by generating a list LN of all possible locations for the next scan step (operation 600). In operation 600, the possible locations are potential next locations for scanning. The process calculates a scan metric (M) for every entry in the list (LN) (operation 602).

[0193] In operation 602, the scan metric is as follows:

$$M = PDF_{int}/t_{tot}$$

where PDF_{int} is the probability density function (PDF) integrated over an area of interest (AOI) for the next potential dwell location. The area of interest for pointing an electromagnetic beam is the region over which the electromagnetic beam exceeds the detection threshold. The area of

interest for an electromagnetic signal receiver is the region of the field of view (FOV) for the electromagnetic signal receiver.

[0194] In this example, the total time, t_{tot} , is given by $t_{tot} = t_{slew} + t_{dwell}$, where t_{slew} is the time it takes to slew the line-of-sight (LOS) from the current dwell location to the next potential location, and t_{dwell} is the time the line of sight dwells at the next potential location. After the dwell at the current location, that dwell location is removed from the list of next possible dwell locations, and the process is repeated until there are no remaining possible dwell locations. The line of sight can be the center of the field of view and is moved to point the electromagnetic signal receiver to different locations.

[0195] The process finds location $L_{N,max}$, which is the location having maximum value of M (operation 604). In operation 604, the location $L_{N,max}$ is the location in the list L_N with the maximum value for M. The system adds the location $L_{N,max}$ to the end of scan-schedule list L_s (operation 606). In operation 606, the scan-schedule list L_s is a scan-schedule list that saves an optimal order of scan steps to use in moving the field of view to different locations.

[0196] The process then removes the location $L_{N,max}$ from list L_N (operation 607). The process determines whether the list L_N is empty (operation 608). In operation 608, If list L_N is not empty, the process returns to operation 602. Otherwise, the process proceeds to scan according to the scan-schedule list L_s (operation 610) with the process terminating thereafter.

[0197] With reference next to FIG. 7, an illustration of a flowchart of a method for pointing an electromagnetic beam is depicted in accordance with an illustrative example. The process in FIG. 7 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 214 in computer system 212 in electromagnetic beam system 220 in FIG. 2.

[0198] The process begins by directing the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located (operation 700). The process moves from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam (operation 702).

[0199] The process continues to move the electromagnetic beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving a confirmation that the electromagnetic beam has encountered the object (operation 704). The process terminates thereafter.

[0200] In one illustrative example, the object can be an uncooperative object. In these examples, an uncooperative object is one that is not providing feedback that can be used as a confirmation that the object is in the location. In other words, if the electromagnetic beam is a laser beam and the object is a satellite, a satellite does not provide any feedback that the laser beam has encountered or eliminated a satellite. An uncooperative object can be, for example, that the satellite is not functioning. However, a confirmation that the laser beam has encountered the satellite can be detected by the reflection of the laser beam from the satellite.

[0201] With reference next to FIG. 8, an illustration of a flowchart of a method for pointing a laser beam is depicted in accordance with an illustrative example. The process in FIG. 8 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 214 in computer system 212 in laser beam system 230 in FIG. 2.

[0202] The process directs the laser beam at a location nearest to a maximum of an uncertainty area in which the satellite is expected to be located (operation 800). The process moves the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam (operation 802). In operation 802, the movement can be movement in the form of a nearest to maximum hexagonal scan with the uncertainty area taking the form of a hexagon.

[0203] The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving a confirmation that the satellite has received the laser beam (operation 804). The process terminates thereafter.

[0204] Turning next to FIG. 9, an illustration of a flowchart of a process for continuing to move a laser beam is depicted in accordance with an illustrative example. The process in this flowchart is an example of an implementation for operation 804 in FIG. 8.

[0205] The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not receiving a confirmation that the satellite has received the laser beam (operation 900). The process terminates thereafter.

[0206] In FIG. 10, an illustration of a flowchart of a process for continuing a laser beam is depicted in accordance with an illustrative example. The process in this flowchart is an example of an implementation for operation 804 in FIG. 8.

[0207] The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not receiving a confirmation that the satellite has received the laser beam (operation 1000). The process terminates thereafter.

[0208] Turning now to FIG. 11, an illustration of a flowchart of a process for moving a laser beam is depicted in accordance with an illustrative example. The process in this flowchart is an example of additional operations that can be performed with the operations in FIG. 8.

[0209] The process moves the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location (operation 1100). The process continues to move the laser beam from the current location to a subsequent neighbor location of the

nearest neighbor from the current location in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold and in response to not receiving a confirmation that the satellite has received the laser beam (operation 1102). The process terminates thereafter.

[0210] In this illustrative example, moving the laser beam to the neighbor location of the nearest neighbor and continuing to move the laser beam from the current location to the subsequent neighbor location of the nearest neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

[0211] With reference next to FIG. 12, an illustration of a flowchart of a process for establishing communications is depicted in accordance with an illustrative example. The process in this figure is an example of an additional operation that can be performed with the operations in FIG. 8.

[0212] The process establishes communications with the satellite in response to receiving the confirmation (operation 1200). The process terminates thereafter. In operation 1200, communications are selected from one of unidirectional communications and bidirectional communications.

[0213] Turning to FIG. 13, an illustration of a flowchart of a process for receiving electromagnetic signals is depicted in accordance with an illustrative example. The process in FIG. 13 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 314 in computer system 312 in electromagnetic signal receiver system 301 in FIG. 3.

[0214] The process moves the field of view of an electromagnetic signal receiver to a location nearest to a maximum of an uncertainty area in which an electromagnetic signal source is expected to be located (operation 1300). Next, the process moves the field of view from the location to a next location nearest to the maximum of the uncertainty area in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location, wherein the next location becomes a current location for the field of view (operation 1302).

[0215] The process continues to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source (operation 1304). The process terminates thereafter. In this example, the movement of the laser beam is in a form of a nearest to maximum hexagonal scan.

[0216] Turning next to FIG. 14, an illustration of a flowchart of a process for continuing to move a field of view is depicted in accordance with an illustrative example. The process in this figure is an example of an implementation for operation 1304 in FIG. 13.

[0217] The process continues to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not detecting the electromagnetic signals from the electromagnetic signal source (operation 1400). The process terminates thereafter.

[0218] In FIG. 15, an illustration of a flowchart of a process for continuing to move a field of view is depicted in accordance with an illustrative example. The process in this figure is an example of an implementation for operation 1304 in FIG. 13.

[0219] The process continues to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not detecting the electromagnetic signals from the electromagnetic signal source (operation 1500). The process terminates thereafter.

[0220] Next in FIG. 16, an illustration of a flowchart of an operation for moving a field of view is depicted in accordance with an illustrative example. The process in this figure is an example of additional operations that can be performed with the process in FIG. 13.

[0221] The process moves the field of view to a neighbor location of a nearest neighbor in response to a time for moving the field of view from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location (operation 1600). The process continues to move the field of view from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to the time for moving the field of view from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold and in response to not detecting the electromagnetic signals from the electromagnetic signal source (operation 1602). The process terminates thereafter.

[0222] Moving the field of view to the neighbor location of the nearest neighbor and continuing to move the field of view from the current location to a subsequent neighbor location of the nearest neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

[0223] Turning now to FIG. 17, an illustration of a flowchart of a process for establishing communications is depicted in accordance with an illustrative example. The process in this flowchart is an example of additional operations that can be performed with the process in FIG. 13.

[0224] The process establishes communications with the electromagnetic signal source in response to detecting the electromagnetic signals (operation 1700). The process terminates thereafter.

[0225] With reference next to FIG. 18, an illustration of a flowchart of a process for detecting electromagnetic signals is depicted in accordance with an illustrative example. The process in FIG. 18 is an example of additional operations that can be performed with the process in FIG. 13.

[0226] The process detects the electromagnetic signals from the electromagnetic signal source in response to detecting selected electromagnetic signals that are greater than a noise level in the field of view (operation 1800). The process terminates thereafter. In operation 1800, the communications are selected from one of unidirectional communications and bidirectional communications.

[0227] The flowcharts and block diagrams in the different depicted examples in FIGS. 6-18 illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative example.

In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0228] In some alternative implementations of an illustrative example, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0229] Turning now to FIG. 19, a block diagram of a data processing system is depicted in accordance with an illustrative example. Data processing system 1900 can be used to implement computer system 212 in FIG. 2 and computer system 312 in FIG. 3.

[0230] In this illustrative example, data processing system 1900 includes communications framework 1902, which provides communications between processor unit 1904, memory 1906, persistent storage 1908, communications unit 1910, input/output (I/O) unit 1912, and display 1914. In this example, communications framework 1902 takes the form of a bus system.

[0231] Processor unit 1904 serves to execute instructions for software that can be loaded into memory 1906. Processor unit 1904 includes one or more processors. For example, processor unit 1904 can be selected from at least one of a multicore processor, a central processing unit (CPU), a graphics processing unit (GPU), a physics processing unit (PPU), a digital signal processor (DSP), a network processor, or some other suitable type of processor. Further, processor unit 1904 can be implemented using one or more heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit 1904 can be a symmetric multi-processor system containing multiple processors of the same type on a single chip.

[0232] Memory 1906 and persistent storage 1908 are examples of storage devices 1916. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, at least one of data, program instructions in functional form, or other suitable information either on a temporary basis, a permanent basis, or both on a temporary basis and a permanent basis. Storage devices 1916 may also be referred to as computer-readable storage devices in these illustrative examples. Memory 1906, in these examples, can be, for example, a random-access memory or any other suitable volatile or non-volatile storage device. Persistent storage 1908 may take various forms, depending on the particular implementation.

[0233] For example, persistent storage 1908 may contain one or more components or devices. For example, persistent storage 1908 can be a hard drive, a solid-state drive (SSD), a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage 1908 also can be removable. For example, a removable hard drive can be used for persistent storage 1908.

[0234] Communications unit 1910, in these illustrative examples, provides for communications with other data processing systems or devices. In these illustrative examples, communications unit 1910 is a network interface card.

[0235] Input/output unit 1912 allows for input and output of data with other devices that can be connected to data processing system 1900. For example, input/output unit 1912 may provide a connection for user input through at least one of a keyboard, a mouse, or some other suitable input device. Further, input/output unit 1912 may send output to a printer. Display 1914 provides a mechanism to display information to a user.

[0236] Instructions for at least one of the operating system, applications, or programs can be located in storage devices 1916, which are in communication with processor unit 1904 through communications framework 1902. The processes of the different examples can be performed by processor unit 1904 using computer-implemented instructions, which may be located in a memory, such as memory 1906.

[0237] These instructions are referred to as program instructions, computer usable program instructions, or computer-readable program instructions that can be read and executed by a processor in processor unit 1904. The program instructions in the different examples can be embodied on different physical or computer-readable storage media, such as memory 1906 or persistent storage 1908.

[0238] Program instructions 1918 are located in a functional form on computer-readable media 1920 that is selectively removable and can be loaded onto or transferred to data processing system 1900 for execution by processor unit 1904. Program instructions 1918 and computer-readable media 1920 form computer program product 1922 in these illustrative examples. In the illustrative example, computer-readable media 1920 is computer-readable storage media 1924.

[0239] Computer-readable storage media 1924 is a physical or tangible storage device used to store program instructions 1918 rather than a medium that propagates or transmits program instructions 1918. Computer-readable storage media 1924 may be at least one of an electronic storage medium, a magnetic storage medium, an optical storage medium, an electromagnetic storage medium, a semiconductor storage medium, a mechanical storage medium, or other physical storage medium. Some known types of storage devices that include these mediums include: a diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device, such as punch cards or pits/lands formed in a major surface of a disc, or any suitable combination thereof.

[0240] Computer-readable storage media **1924**, as that term is used in the present disclosure, is not to be construed as storage in the form of transitory signals per se, such as at least one of radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide, light pulses passing through a fiber optic cable, electrical signals communicated through a wire, or other transmission media.

[0241] Further, data can be moved at some occasional points in time during normal operations of a storage device. These normal operations include access, de-fragmentation or garbage collection. However, these operations do not render the storage device as transitory because the data is not transitory while the data is stored in the storage device.

[0242] Alternatively, program instructions **1918** can be transferred to data processing system **1900** using a computer-readable signal media. The computer-readable signal media are signals and can be, for example, a propagated data signal containing program instructions **1918**. For example, the computer-readable signal media can be at least one of an electromagnetic signal, an optical signal, or any other suitable type of signal. These signals can be transmitted over connections, such as wireless connections, optical fiber cable, coaxial cable, a wire, or any other suitable type of connection.

[0243] Further, as used herein, “computer-readable media **1920**” can be singular or plural. For example, program instructions **1918** can be located in computer-readable media **1920** in the form of a single storage device or system. In another example, program instructions **1918** can be located in computer-readable media **1920** that is distributed in multiple data processing systems. In other words, some instructions in program instructions **1918** can be located in one data processing system while other instructions in program instructions **1918** can be located in another data processing system. For example, a portion of program instructions **1918** can be located in computer-readable media **1920** in a server computer while another portion of program instructions **1918** can be located in computer-readable media **1920** located in a set of client computers.

[0244] The different components illustrated for data processing system **1900** are not meant to provide architectural limitations to the manner in which different examples can be implemented. In some illustrative examples, one or more of the components may be incorporated in or otherwise form a portion of, another component. For example, memory **1906**, or portions thereof, may be incorporated in processor unit **1904** in some illustrative examples. The different illustrative examples can be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system **1900**. Other components shown in FIG. 19 can be varied from the illustrative examples shown. The different examples can be implemented using any hardware device or system capable of running program instructions **1918**.

[0245] Some features of the illustrative examples for pointing an electromagnetic beam are described in the following clauses. These clauses are examples of features and are not intended to limit other illustrative examples.

Clause 1

[0246] A laser beam transmission system comprising:

[0247] a laser beam system configured to transmit a laser beam;

[0248] a controller configured to control the laser beam system to:

[0249] direct the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

[0250] move the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam; and

[0251] continue to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 2

[0252] The laser beam transmission system of clause 1, wherein a movement of the laser beam is in a form of a nearest to maximum hexagonal scan.

Clause 3

[0253] The laser beam transmission system of clause 1, wherein in continuing to move the laser beam, the controller is configured to:

[0254] continue to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 4

[0255] The laser beam transmission system of clause 1, wherein in continuing to move the laser beam, the controller is configured to:

[0256] continue to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 5

[0257] The laser beam transmission system of clause 1, wherein the controller is configured to control the laser beam system to:

[0258] move the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location; and

[0259] continue to move the laser beam from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to the time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 6

[0260] The laser beam transmission system of clause 5, wherein in moving the laser beam to the neighbor location of the nearest neighbor and continuing to move the laser beam from the current location to the subsequent neighbor location of the nearest neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

Clause 7

[0261] The laser beam transmission system of clause 1, wherein the controller is configured to:

[0262] establish communications with the satellite in response to receiving the confirmation.

Clause 8

[0263] The laser beam transmission system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0264] The laser beam transmission system of clause 1, wherein the laser beam is selected from a group comprising a continuous laser beam and a pulsed laser beam.

Clause 10

[0265] An electromagnetic beam transmission system comprising:

[0266] an electromagnetic beam system configured to transmit an electromagnetic beam;

[0267] a controller configured to control the electromagnetic beam transmission system to:

[0268] direct the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0269] move the electromagnetic beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam; and

[0270] continue to move the electromagnetic beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the electromagnetic beam has encountered the object.

Clause 11

[0271] The electromagnetic beam transmission system of clause 10, wherein the object is selected from a group comprising an uncooperative object, a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power

plant, a bridge, a dam, a house, a manufacturing facility, a building, and an electromagnetic beam receiver.

Clause 12.

[0272] An electromagnetic beam transmission system comprising:

[0273] an electromagnetic beam system configured to transmit an electromagnetic beam;

[0274] a controller configured to control the electromagnetic beam transmission system to:

[0275] direct the electromagnetic beam to a location in an uncertainty area using a scan metric, wherein the uncertainty area is one in which an object is expected to be located;

[0276] move the electromagnetic beam from the location to a next location using the scan metric in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam; and

[0277] continue to move the electromagnetic beam from the current location to the next location using the scan metric in response to not receiving the confirmation that the electromagnetic beam has encountered the object.

Clause 13

[0278] The electromagnetic beam transmission system of clause 12, wherein the controller selects the next location in the uncertainty area from a set of candidate locations that has a highest value for the scan metric, wherein the scan metric is as follows:

$$M = \text{PDFint}/t_{\text{tot}}$$

[0279] where PDFint is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time t_{tot}=tslew+tdwell, tslew is a time to slew a line-of-sight from the current location to the next potential location, and tdwell is a time the line of site dwells at the next potential location.

Clause 14

[0280] A method for pointing a laser beam, the method comprising:

[0281] directing the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

[0282] moving the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam; and

[0283] continuing to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 15

[0284] The method of clause 14, wherein a movement of the laser beam is in a form of a nearest to maximum hexagonal scan.

Clause 16

[0285] The method of clause 14, wherein continuing to move the laser beam comprises:

[0286] continuing to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 17

[0287] The method of clause 14, wherein continuing to move the laser beam comprises:

[0288] continuing to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 18

[0289] The method of clause 14 further comprising:

[0290] moving the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location; and

[0291] continuing to move the laser beam from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to the time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 19

[0292] The method of clause 18, wherein moving the laser beam to the neighbor location of the nearest neighbor and continuing to move the laser beam from the current location to the subsequent neighbor location of the nearest neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

Clause 20

[0293] The method of clause 14 further comprising:

[0294] establishing communications with the satellite in response to receiving the confirmation.

Clause 21

[0295] The method of clause 20, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0296] The method of clause 14, wherein the laser beam is selected is selected from a group comprising a continuous laser beam and a pulsed laser beam.

Clause 23

[0297] A method for pointing an electromagnetic beam, the method comprising:

[0298] directing the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0299] moving the electromagnetic beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam; and

[0300] continuing to move the electromagnetic beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the electromagnetic beam has encountered the object.

[0301] With respect to receiving electromagnetic signals, an example of the present disclosure provides an electromagnetic signal receiver system comprising an electromagnetic signal receiver having a field of view in which electromagnetic signals are received and a controller. The controller is configured to control the electromagnetic signal receiver to move the field of view to a location nearest to a maximum of an uncertainty area in which an electromagnetic signal source is expected to be located. The controller is configured to control the electromagnetic signal receiver to move the field of view from the location to a next location nearest to the maximum of the uncertainty area in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location. The next location becomes a current location for the field of view. The controller is configured to control the electromagnetic signal receiver to continue to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

[0302] Another example of the present disclosure provides an electromagnetic signal receiver system comprising an electromagnetic signal receiver having a field of view in which electromagnetic signals are received and a controller. The controller is configured to control the electromagnetic signal receiver to move the field of view of the electromagnetic signal receiver to a location in an uncertainty area using a scan metric, wherein the uncertainty area is an area in which an electromagnetic signal source is expected to be located. The controller is configured to control the electromagnetic signal receiver to move the field of view from the location to a next location using the scan metric in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location. The next location

becomes a current location for the field of view. The controller is configured to control the electromagnetic signal receiver to continue to move the field of view from the current location to the next location using the scan metric in response to not detecting the electromagnetic signals from the electromagnetic signal source.

[0303] Yet another example of the present disclosure provides a method for receiving electromagnetic signals. A field of view of an electromagnetic signal receiver is moved to a location nearest to a maximum of an uncertainty area in which an electromagnetic signal source is expected to be located. The field of view is moved from the location to a next location nearest to the maximum of the uncertainty area in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location. The next location becomes a current location for the field of view. The field of view is continued to be moved from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

[0304] Some features of the illustrative examples for receiving electromagnetic signals are described in the following clauses. These clauses are examples of features and are not intended to limit other illustrative examples.

Clause 1

[0305] An electromagnetic signal receiver system comprising:

[0306] an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;

[0307] a controller configured to control the electromagnetic signal receiver to:

[0308] move the field of view to a location nearest to a maximum of an uncertainty area in which an electromagnetic signal source is expected to be located;

[0309] move the field of view from the location to a next location nearest to the maximum of the uncertainty area in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location, wherein the next location becomes a current location for the field of view; and

[0310] continue to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 2

[0311] The electromagnetic signal receiver system of clause 1, wherein a movement of the field of view is in a form of a nearest to maximum hexagonal scan. Clause 3.

[0312] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0313] continue to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 4

[0314] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0315] continue to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 5

[0316] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to control the electromagnetic signal receiver system to:

[0317] move the field of view to a neighbor location of a nearest neighbor in response to a time for moving the field of view from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location; and

[0318] continue to move the field of view from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to a time for moving the field of view from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 6

[0319] The electromagnetic signal receiver system of clause 5, wherein moving the field of view to the neighbor location of the nearest neighbor and continuing to move the field of view from the current location to the subsequent neighbor location of the nearest neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

Clause 7

[0320] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:

[0321] establish communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 8

[0322] The electromagnetic signal receiver system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0323] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:

[0324] detect the electromagnetic signals from the electromagnetic signal source in response to detecting

selected electromagnetic signals that are greater than a noise level in the field of view.

Clause 10

[0325] The electromagnetic signal receiver system of clause 1, wherein the electromagnetic signal receiver is selected from a group comprising a telescope.

Clause 11

[0326] The electromagnetic signal receiver system of clause 1, wherein the electromagnetic signals are selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, or ultraviolet light signals.

Clause 12

[0327] An electromagnetic signal receiver system comprising:

[0328] an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;

[0329] a controller configured to control the electromagnetic signal receiver to:

[0330] move the field of view of the electromagnetic signal receiver to a location in an uncertainty area using a scan metric, wherein the uncertainty area is an area in which an electromagnetic signal source is expected to be located;

[0331] move the field of view from the location to a next location using the scan metric in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location, wherein the next location becomes a current location for the field of view; and

[0332] continue to move the field of view from the current location to the next location using the scan metric in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 13

[0333] The electromagnetic signal receiver system of clause 12, wherein the controller selects the next location in the uncertainty area from a set of candidate locations that has a highest value for the scan metric, wherein the scan metric is as follows:

$$M = \text{PDFint}/t_{\text{tot}}$$

[0334] where PDFint is a probability density function integrated over an area of interest for a next potential location and t_{tot} is a total time t_{tot}=t_{slew}+t_{dwell}, t_{slew} is a time to slew a line-of-sight from the current location to the next potential location, and t_{dwell} is a time the line of site dwells at the next potential location.

Clause 14

[0335] A method for receiving electromagnetic signals comprising:

[0336] moving a field of view of an electromagnetic signal receiver to a location nearest to a maximum of an

uncertainty area in which an electromagnetic signal source is expected to be located;

[0337] moving the field of view from the location to a next location nearest to the maximum of the uncertainty area in response to not detecting the electromagnetic signals from the electromagnetic signal source at the location, wherein the next location becomes a current location for the field of view; and

[0338] continuing to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 15

[0339] The method of clause 14, wherein a movement of the field of view is in a form of a nearest to maximum hexagonal scan.

Clause 16

[0340] The method of clause 14, wherein continuing to move the field of view comprises:

[0341] continuing to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

[0342] 17. The method of claim 14, continuing to move the field of view comprises:

[0343] continuing to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a continuous movement from one location to another location in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 18

[0344] The method of clause 14 further comprising:

[0345] moving the field of view to a neighbor location of a nearest neighbor in response to a time for moving the field of view from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location; and

[0346] continuing to move the field of view from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to not detecting the electromagnetic signals from the electromagnetic signal source from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not detecting the electromagnetic signals from the electromagnetic signal source.

Clause 19

[0347] The method of clause 18, wherein moving the field of view to the neighbor location of the nearest neighbor and continuing to move the field of view from the current location to the subsequent neighbor location of the nearest

neighbor from the current location is part of a nearest neighbor scan selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, and a raster scan.

Clause 20

[0348] The method of clause 14 further comprising:

[0349] establishing communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 21

[0350] The method of clause 20 wherein the communications is selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0351] The method of clause 14 further comprising:

[0352] detecting the electromagnetic signals from the electromagnetic signal source in response to detecting selected electromagnetic signals that are greater than a noise level in the field of view.

Clause 23

[0353] The method of clause 14, wherein the electromagnetic signals are selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, and ultraviolet light signals.

[0354] The illustrative embodiments recognize and take into account one or more different considerations as described herein. During the initial acquisition in establishing the communications link, a time efficient scanning method for pointing laser beams at satellites is desired. Various scanning methods can be used to point a laser beam from a transmitting satellite to a receiving satellite. In satellite communications, lasers beams can have different wavelengths such as, for example, a wavelength of about 1064 nm in the near infrared wavelength range, 1550 nm in the visible wavelength range, and 532 nm in the visible wavelength range.

[0355] With the distances separating satellites, establishing communications between the satellites using laser beams requires a time efficient scanning technique. The speed at which an area to be scanned to locate a satellite is important in establishing the communications link as quickly as possible. For example, a service-level agreement (SLA) may require establishing a communications link within a specified amount of time.

[0356] Using the most time efficient technique for scanning an area to locate a satellite is important in quickly establishing communications links between satellites using laser beams to meet service-level agreements (SLAs) and other requirements or agreements.

[0357] Current laser scanning methods include a continuous spiral scan, a step spiral scan, a segment scan, and a raster scan. These types of scans for establishing the communications link may not be sufficiently fast to establish communications as quickly as needed to meet various requirements that may be present.

[0358] Currently, the different parameters for scanning for a satellite are fixed during the entire scan. However, given the probability of finding a satellite typically changes from location to location, the scan parameters can be changed from location to location to efficiently search for the satel-

lite. In some cases, the scan parameters can be changed between some locations and not all of the locations.

[0359] With reference now to FIG. 20, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment 2000 includes components that can be implemented in hardware such as the hardware in satellite 101 and satellite 102 in FIG. 1. In this example, electromagnetic beam transmission system 2002 is an example of an implementation of electromagnetic beam transmission system 202 in FIG. 2. The components can be implemented using components in electromagnetic beam transmission system 2002 in electromagnetic beam transmission system 202 in FIG. 2.

[0360] In this illustrative example, electromagnetic beam transmission system 2002 can point the transmission of electromagnetic beam 2003 at object 2093. In this example, object 2093 can be electromagnetic beam receiver 2004. Electromagnetic beam receiver 2004 can be connected to object 2093 in this example. For example, object 2093 can be satellite 2038.

[0361] In this illustrative example, electromagnetic beam transmission system 2002 comprises electromagnetic beam system 2020 and controller 2014. In this example, controller 214 is located in computer system 2012. As depicted, computer system 2012 is also part of electromagnetic beam transmission system 2002.

[0362] Electromagnetic beam system 2020 is a physical hardware system. This hardware system is configured to transmit electromagnetic beam 2003.

[0363] Controller 2014 can be implemented in a similar manner as controller 214 in FIG. 2 in which program instructions 2018 can be used to implement controller 2014 that are executed by a number of processor units 2016 in computer system 2012. In this example, controller 2014 includes processes similar to those in controller 214 in FIG. 2 but also includes additional processes for controlling the manner in which a scan is performed. Program instructions 2018, the number of processor units 2016, and computer system 2012 can be implemented in a similar manner to program instructions 218, processor units 216, and computer system 212 in FIG. 2.

[0364] In this illustrative example, controller 2014 controls electromagnetic beam transmission system 2002 to direct electromagnetic beam 2003 at location 2022 in search area 2081 in which object 2093 is expected to be located. In other words, search area 2081 is an area in which object 2093 is believed to be present. This search area 2081 can have a number of different shapes selected from a group comprising a hexagon, a circle, an octagon, an ellipse, or some other shape. Object 2093 may not actually be in search area 2081. In some cases, search area 2081 can be selected as an area for searching with the intent of locating object 2093.

[0365] As depicted, electromagnetic beam 2003 has beam spot 2061. In this example, beam spot 2061 is a diameter of electromagnetic beam 2003 at a location in search area 2081. In this example, beam spots can correspond to locations in search area 2081. For example, location 2022 in search area 2081 can have a size and shape that corresponds to the size and shape of beam spot 2061 when the electromagnetic beam 2003 is directed at location 2022.

[0366] In one illustrative example, electromagnetic beam receiver 2004 is connected to object 2093. When one

component is “connected” to another component, the connection is a physical connection. For example, a first component, electromagnetic beam receiver **2004**, can be considered to be physically connected to a second component, object **2093**, by at least one of being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, or connected to the second component in some other suitable manner. The first component also can be connected to the second component using a third component. The first component can also be considered to be physically connected to the second component by being formed as part of the second component, an extension of the second component, or both. In some examples, the first component can be physically connected to the second component by being located within the second component.

[0367] In this example, controller **2014** controls electromagnetic beam system **2020** to direct electromagnetic beam **2003** at central location **2023** in search area **2081** in which object **2093** is expected to be located. In one example, object **2093** is satellite **2038**. Central location **2023** is the first location for performing hexagonal scan **2040** and is at the center of search area **2081**. Hexagonal scan **2040** occurs with the movement of electromagnetic beam **2003** to scan search area **2081**. In this example, hexagonal scan **2040** has a shape of a hexagon. This type of search can be used with search area **2081** in the form of a hexagon, a circle, an octagon or some other shape that has radial symmetry. For example, if search area **2081** has the shape of a circle, this circle falls within the area scanned by hexagonal scan **2040**. Locations that fall outside of search area **2081** when using hexagonal scan **2040** can be skipped.

[0368] In this example, controller **2014** controls electromagnetic beam system **220** to move electromagnetic beam **2003** to next location **2024** that is nearest neighbor **2044** to central location **2023** in response to not receiving confirmation **2027** that object **2093** is at central location **2023**. Next location **2024** becomes current location **2025** for the electromagnetic beam **2003**.

[0369] Further in this example, controller **214** controls electromagnetic beam system **2020** to adjust a number of scan parameters **2070** during a movement of the electromagnetic beam system **2020** to scan search area **2081**. The number of scan parameters **2070** changes during scanning of search area **2081**. In other words, the number of scan parameters **2070** does not remain fixed during the entire scan. In this illustrative example, the number of scan parameters **2070** can be adjusted by controller **2014** controlling electromagnetic beam system **2020**. In this illustrative example, the number of scan parameters **2070** can be adjusted to increase the likelihood that electromagnetic beam **2003** hits object **2093** in search area **2081**.

[0370] In this depicted example, controller **2014** controls electromagnetic beam system **2020** to continue to move electromagnetic beam **2003** from current location **2025** to next location **2024** that is nearest neighbor **2044** to current location **2025** in response to not receiving confirmation **2027** that object **2093** has received electromagnetic beam **2003**.

[0371] This type of movement of electromagnetic beam **2003** is nearest neighbor scan **2042**. In other words, the movement of electromagnetic beam **2003** is from current location **2025** to subsequent location **2045** that is nearest neighbor **2044** to current location **2025**. In this example,

each subsequent neighbor location that electromagnetic beam **2003** moves to is adjacent to current location **2025**. Thus, with this type of movement, the scan performed using electromagnetic beam **2003** is both hexagonal scan **2040** and nearest neighbor scan **2042**. This time of scan can also be referred to as a honeycomb-like laser beam scan.

[0372] In this illustrative example, confirmation **227** can take a number of different forms. For example, confirmation **2027** can be a reply or acknowledgment sent in a return electromagnetic beam to electromagnetic beam system **2020**. In this example, electromagnetic beam system **220** can also receive electromagnetic beams. In another illustrative example, confirmation can be sent through another transmission to controller **2014** through another device such as a radiofrequency receiver or other type of receiver.

[0373] In one illustrative example, electromagnetic beam **2003** can take the form of laser beam **2033**. Further, laser beam **2033** can be selected from a group comprising a continuous laser beam and a pulsed laser beam. Electromagnetic beam system **2020** can be laser beam system **2030** and object **2093** can take the form of satellite **2038**. In this example, electromagnetic beam transmission system **2002** is laser beam transmission system **2011**.

[0374] In this example, controller **2014** controls laser beam system **2030** to direct laser beam **2033** at central location **2023** in search area **2081** in which satellite **2038** is expected to be located. Controller **2014** also controls laser beam system **2030** to move laser beam **2033** to next location **2024** that is nearest neighbor **2044** to central location **2023** in response to not receiving confirmation **2027** that satellite **2038** is at central location **2023**. In this example, next location **2024** becomes current location **2025** for laser beam **2033**.

[0375] Further, controller **2014** controls laser beam system **2030** to adjust a number of scan parameters **2070** during a movement of laser beam **2033** to scan search area **2081**. As a result, the number of scan parameters **2070** can change during every movement of laser beam **2033** or during one or more movements of laser beam **2033** to scan search area **2081**.

[0376] For example, controller **2014** can change the number of scan parameters **2070** from location to location. The adjustment to the number of scan parameters **2070** is made to efficiently search for satellite **2038**. In some cases, the number of scan parameters **2070** can be changed between some locations and not all of the locations.

[0377] In this illustrative example, the number of scan parameters **2070** can be adjusted to increase the likelihood that laser beam **2033** hits satellite **2038** in search area **2081**. The number of scan parameters **2070** can be selected from at least one of overlap **2071**, beam divergence **2072**, dwell time **2073**, or other suitable scan parameters. In this illustrative example, controller **2014** can adjust the number of scan parameters **2070** during movement of laser beam **2033**.

[0378] In the illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing overlap **2071** during the movement of laser beam **2033** to scan search area **2081**.

[0379] In one illustrative example, search area **2081** comprises locations **2082** around central location **2023** are arranged in concentric layers **2083** in search area **2081**. These layers can also be referred to as rings and in particular as concentric rings. Each layer in concentric layers **2083** is larger or farther away from central location **2023** than a prior

layer in concentric layers **2083**. Central location **2023** can be considered a first layer in concentric layers **2083**.

[0380] With these concentric layers of locations **2082**, controller **2014** adjusts the number of scan parameters **2070** by increasing overlap **2071** at each layer in concentric layers **2083** in the search area **2081** during the movement of laser beam **2033** to scan search area **2081**. Overlap **2071** at locations **2082** in a layer is uniform. In other words, overlap **2071** is the same for all locations in a layer.

[0381] In this example, nearest neighbor scan **2042** involves laser beam **2033** moving along a path from central location **2023** that progresses outward to the perimeter of search area **2081**. Increased overlap results in more time being needed to perform nearest neighbor scan **2042**.

[0382] The amount of overlap in different segments of the path for the scan can be selected such that the time needed to scan the entire path of nearest neighbor scan **2042** is the same as if the path used the same amount of overlap for the entire path. In other words, different segments of the path can have different amounts of overlap such that the total overlap present along the path for the segments can be the same as the total overlap for a path in which the amount of overlap is the same along the path for the scan.

[0383] In another illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing a divergence of laser beam **2033** during the movement of the laser beam **2033** to scan search area **2081**. In one illustrative example, in increasing beam divergence **2072**, controller **2014** increases beam divergence **2072** of laser beam **2033** at each layer in concentric layers **2083** in the search area **2081** during the movement of the laser beam to scan search area **2081**. With this example, beam divergence **2072** of the laser beam **2033** at locations **2082** in a layer is uniform.

[0384] A smaller divergence may increase the ability to detect satellite **2038** at a particular location. However, the smaller divergence means that the path for nearest neighbor scan **2042** is longer to cover search area **2081**. As a result, increasing beam divergence **2072** as laser beam **2033** moves farther away from central location **2023** results in that portion of the path needing less time to cover search area **2081**. As a result, the same amount of time is used for the scan as if beam divergence **2072** remained constant along the entire path for nearest neighbor scan **2042**.

[0385] In still another illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing dwell time **2073** for laser beam **2033** during the movement of laser beam **2033** to scan search area **2081**. A longer dwell time increases the ability to detect satellite **2038** at a particular location. However, the increased dwell time results in the need for more time to perform nearest neighbor scan **2042**. As a result, decreasing the dwell time as laser beam **2033** moves away from central location **2023** can reduce the scan time for that portion of the path for nearest neighbor scan **2042**.

[0386] Further, in increasing dwell time **2073**, controller **2014** can increase dwell time **2073** for laser beam **2033** at each layer in concentric layers **2083** in search area **2081** during the movement of laser beam **2033** to scan search area **2081**. With this example, dwell time **2073** of laser beam **2033** at locations **2082** in a layer is uniform.

[0387] In this manner, controller **2014** can adjust a number of scan parameters **2070** such that the time to perform nearest neighbor scan **2042** can be performed within a desired amount of time. In other words, rather than having

a longer dwell time along the entire path for nearest neighbor scan **2042**, the dwell time can decrease as the scan progresses. This change in dwell time can be made during the scan because the likelihood of satellite **2038** being in a location farther away from central location **2023** is lower than at central location **2023**.

[0388] Controller **2014** controls laser beam system **2030** to continue to move laser beam **2033** from current location **2025** to next location **2024** that is nearest neighbor **2044** to current location **2025** in response to not receiving confirmation **2027** that satellite **2038** has received laser beam **2033**.

[0389] In these examples, the moving or directing of laser beam **2033** can also be referred to as pointing laser beam **2033**. Further, laser beam **2033** can be selected from one of unidirectional communications and bidirectional communications.

[0390] In this example, confirmation **2027** can be received from satellite **2038**. Satellite **2038** can send a return laser beam at the same angle as the incoming laser beam.

[0391] In this illustrative example, controller **2014** can perform a number of operations in response to locating satellite **2038**. For example, controller **2014** can establish communications with satellite **2038** in response to receiving confirmation **2027** that satellite **2038** has received laser beam **2033**.

[0392] In one illustrative example, one or more technical solutions are present that overcome a technical problem with pointing an electromagnetic beam, such as a laser beam, at a receiver connected to a platform. As a result, one or more illustrative examples enable pointing a laser beam at an object in an efficient manner. The pointing of the laser beam is performed in a manner that adjusts a number of scan parameters during the scanning process used to scan an area such as search area **2081**.

[0393] Computer system **2012** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware, or a combination thereof. As a result, computer system **2012** operates as a special purpose computer system in which controller **2014** in computer system **2012** enables adjusting scan parameters such that locating an object can be performed more quickly as compared to current techniques. Controller **2014** transforms computer system **2012** into a special purpose computer system as compared to currently available general computer systems that do not have controller **2014**.

[0394] In the illustrative example, the use of controller **2014** in computer system **2012** integrates processes into a practical application for pointing electromagnetic beam **2003** at electromagnetic beam receiver **2004**. In these different examples, the processes adjusts scan parameters **2070** during movement of electromagnetic beam **2003**. In other words, the number of scan parameters **2070** are not fixed during the scanning of search area **2081**.

[0395] The illustration of electromagnetic signal environment **2000** in FIG. **20** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or

more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0396] For example, electromagnetic beam 2003 has been described as being laser beam 2033. Electromagnetic beam 2003 can take other forms in other illustrative examples such as a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam.

[0397] As another example, object 2093 can take a number of different forms in addition to satellite 2038. For example, object 2093 can be selected from a group comprising an uncooperative object, a platform, a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, an electromagnetic beam receiver, and other suitable types of objects.

[0398] As another example, controller 2014 can control one or more electromagnetic beam systems in addition to or in place of electromagnetic beam system 2020. Further, the system can be used with an electromagnetic signal receiver system as described below with respect to FIG. 3.

[0399] In one illustrative example, the number of scan parameters 2070 changes between concentric layers 2083. In other illustrative examples, the number of scan parameters 2070 can change at other locations to scan search area 2081. For example, the number of scan parameters 2070 can change within a layer in concentric layers 2083. The locations at which the number of scan parameters 2070 change can be selected to increase the likelihood that electromagnetic beam 2003, such as laser beam 2033, hits object 2093.

[0400] Pointing an electromagnetic signal receiver at an electromagnetic signal source can also take more time than desired and is more challenging than desired. With reference now to FIG. 21, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment 2100 includes components that can be implemented in hardware such as the hardware shown in satellite 120 and receiver 122 and telescope 123 in FIG. 1.

[0401] In the illustrative example, electromagnetic signal receiver system 2101 in electromagnetic signal environment 2100 can be pointed to receive electromagnetic signals 2103 from electromagnetic signal source 2104. In this example, electromagnetic signal receiver system 2101 comprises electromagnetic signal receiver 2102 and controller 2114. In this example, controller 2114 is located in computer system 2112. As depicted, computer system 2112 is part of electromagnetic signal receiver system 2101 in this example. In this example, these components can be examples of components in electromagnetic signal receiver system 301 in FIG. 3. The components can be implemented using components in electromagnetic signal receiver system 301 in FIG. 3.

[0402] In this illustrative example, electromagnetic signal source 2104 generates electromagnetic signals 2103. Elec-

tromagnetic signals 2103 can take a number of different forms. For example, electromagnetic signals 2103 can be in a beam, collimated beam, omnidirectional signals, directional signals, or other types of radiation patterns for forms. Electromagnetic signals 2103 can be selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, ultraviolet light signals, or other types of electromagnetic signals.

[0403] Electromagnetic signal source 2104 can take a number of different forms. For example, electromagnetic signal source 2104 can be a platform selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[0404] Electromagnetic signal receiver 2102 is a physical hardware system that can receive electromagnetic signals 2103. Electromagnetic signal receiver 2102 has field of view 2121. In this illustrative example, hardware such as an antenna, a radio receiver, a photo detector, or other device that can detect electromagnetic signals 2103 that are in field of view 2121 can be used. This hardware is unable to detect or use electromagnetic signals 2103 outside the field of view 2121.

[0405] The hardware can include receiver 2183. Receiver 2183 can be implemented using a receiver such as a photodetector, a photodiode system, a phase array antenna, focal plane array (FPA), cell (QC), or other suitable types of hardware.

[0406] In another illustrative example, electromagnetic signal receiver 2102 can include telescope 2182. Telescope 2182 is a hardware component collecting incoming electromagnetic signals onto a detector in receiver 2183.

[0407] In this illustrative example, field of view (FOV) 2121 is the view that electromagnetic signal receiver 2102 has to see or receive electromagnetic signals 2103. Field of view 2121 may be described as the angular range within which electromagnetic signal receiver 2102 can detect or receive electromagnetic signals 2103. In this example, field of view 2121 can be defined by telescope 2182.

[0408] In this example, field of view 2121 can also be described as the instantaneous angle subtended by the scanning system that exceeds the detection threshold.

[0409] Controller 2114 can be implemented in a similar manner as controller 314 in FIG. 3 in which program instructions 2118 can be used to implement controller 2114 that are executed by a number of processor units 2116 in computer system 2112. In this example, controller 2114 includes processes similar to those in controller 314 in FIG. 3 but also includes additional processes for controlling the manner in which a scan is performed to detect electromagnetic signals 2103. Program instructions 2118, the number of processor units 2016, and computer system 2112 can be implemented in a similar manner to program instructions 318, processor units 316, and the computer system 312 in FIG. 3.

[0410] Controller 2114 is configured to control the operation of electromagnetic signal receiver 2102. For example, controller 2114 can control electromagnetic signal receiver 2102 in search area 2181. Search area 2181 is an area in which electromagnetic signal source 2104 is believed to be present. This search can be performed by moving field of view 2121 to scan search area 2181.

[0411] In one illustrative example, search area 2181 comprises locations 2192 around central location 2123 that are arranged in concentric layers 2193 in search area 2081. These layers can also be referred to as rings and in particular as concentric rings. Each layer in concentric layers 2193 is larger or farther away from central location 2123 than a prior layer in concentric layers 2193. Central location 2123 can be considered a first layer in concentric layers 2193.

[0412] In this illustrative example, controller 2114 controls electromagnetic signal receiver 2102 to move field of view 2121 of electromagnetic signal receiver 2102 to central location 2123 in search area 2181 in which electromagnetic signal source 2104 is expected to be located. This moving of field of view 2121 can also be referred to as pointing field of view 2121. Central location 2123 is the first location for performing hexagonal scan 2140 and is at the center of search area 2081. Hexagonal scan 2140 occurs from moving field of view 2121 to scan search area 2181.

[0413] Further, in this example, controller 2114 moves field of view 2121 of electromagnetic signal receiver 2102 to next location 2124 that is nearest neighbor 2144 to central location 2123 in response to not detecting electromagnetic signals 2103 from electromagnetic signal source 2104 at central location 2123. In this example, next location 2124 becomes current location 2125 for field of view 2121. This type of movement of field of view 2121 is nearest neighbor scan 2142. Thus, the movement of field of view 2121 can be both hexagonal scan 2140 and nearest neighbor scan 2142.

[0414] Thus, with this type of movement, the scan performed by moving field of view 2121 is both hexagonal scan 2040 and nearest neighbor scan 2042.

[0415] Further in this example, controller 314 adjusts a number of scan parameters 2170 during a movement of field of view 2121 to scan search area 2181. In this illustrative example, the number of scan parameters 2170 can be adjusted by controller 2114 controlling electromagnetic signal receiver 2102. The number of scan parameters 2170 can be selected from at least one of overlap 2171, beam divergence 2172, dwell time 2173, or other suitable scan parameters. In this illustrative example, the number of scan parameters 2170 can be adjusted to increase the likelihood that electromagnetic signals 2103 from electromagnetic signal source 2104 are detected.

[0416] In this illustrative example, the number of scan parameters 2170 can be changed during movement of field of view 2121 using the same type of adjustments as described with respect to controller 2014 adjusting scan parameters 2070 while controlling laser beam system 2030 to move laser beam 2033 to scan search area 2081 in FIG. 20.

[0417] In this illustrative example, controller 2114 can detect electromagnetic signals 2103 from electromagnetic signal source 2104 in response to detecting selected electromagnetic signals that are greater than a noise level in field of view 2121. In response to detecting electromagnetic signals 303, controller 2114 can establish communications with electromagnetic signal source 2104 or perform other

actions. As another example, controller 2114 can identify a location of electromagnetic signal source 2104 in response to detecting electromagnetic signals 2103 in a particular location in locations 2192 in search area 2181.

[0418] The illustration of electromagnetic signal environment 2100 in FIG. 21 is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0419] For example, electromagnetic signal receiver system 2101 can be connected to platform 2105. In this example, platform 2105 can be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0420] In another illustrative example, controller 2114 can be located in a separate platform or location from electromagnetic signal receiver system 2101. Additionally, electromagnetic signal receiver system 2101 can be used with an electromagnetic signal transmission system such as electromagnetic beam transmission system 2002 in FIG. 20. In this example, a single controller can be present that controls both systems and that controller can be in a separate location from the systems.

[0421] In yet another illustrative example, controller 2114 can be controlled by one or more electromagnetic signal receiver systems in addition to or in place of electromagnetic signal receiver system 2101.

[0422] Further with this example, search area 2181 is a shape of hexagon 2191. In other examples, the scan area can have a shape selected from a group comprising a hexagon, a circle, an octagon, an ellipse, or some other suitable shape in addition to or in place of hexagon 2191.

[0423] With reference next to FIG. 22, an illustration of hexagonal scans performed using scan parameters that are adjusted during the scanning of a search area is depicted in accordance with an illustrative embodiment. In this illustrative example, hexagonal scans 2200 are hexagonal scans in which a number of scan parameters are adjusted for hexagonal scan 2201 while performing a scan. In other words, one or more scan parameters can change during the performance of the scan of the search area.

[0424] As depicted, spiral scans 2202 include spiral scan 2221, spiral scan 2222, and spiral scan 2223. These spiral scans provide a visual illustration of adjustments to scan parameters that occur during the performance of these spiral scans. In this example, spiral scans 2202 have been selected because the scans provide a clear visualization of changes to scan parameters.

[0425] In this example, these spiral scans include illustrative adjustments to overlap 2211, beam divergence 2212,

and dwell time 2213. As depicted, overlap 2211 decreases as spiral scan 2221 progresses. Further in this example, beam divergence 2212 increases as spiral scan 2222 progresses. Further in this example, dwell time 2213 decreases as spiral scan 2223 progresses.

[0426] In this example, hexagonal scan 2231 is hexagonal scan 2201 with adjustments to overlap 2211. In this example, the overlap decreases as hexagonal scan 2231 progresses. In this example, the increase in overlap occurs at each layer in the concentric layers forming hexagonal scan 2231.

[0427] In this example, hexagonal scan 2241 is hexagonal scan 2201 with adjustments to beam divergence 2212. In this example, beam divergence 2212 increases as hexagonal scan 2241 progresses. In this example, the increase in beam divergence 2212 occurs at each layer in the concentric layers forming hexagonal scan 2241.

[0428] Further, hexagonal scan 2251 is hexagonal scan 2201 with adjustments to dwell time 2213. In this example, dwell time 2213 increases as hexagonal scan 2251 progresses. In this example, the increase in dwell time 2213 occurs at each layer in the concentric layers forming hexagonal scan 2251.

[0429] In this illustrative example, the adjustments to the number of scan parameters are performed to reduce the amount of time needed to perform a scan as compared to maintaining the same value for scan parameters of the entire scan. As a result, scans can be performed with a greater likelihood of hitting an object such as a satellite while performing scans within a selected amount of time. This selected amount time may be set through various policies such as service-level agreements, scan time requirements or other rules or guidelines.

[0430] Turning to FIG. 23, an illustration of a hexagon scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan 2231 is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved to perform hexagonal scan 2231.

[0431] For example, hexagonal scan 2231 starts at central location 2301 and moves from location to location in layers that form concentric layers 2300.

[0432] As depicted, the beam spots are organized as concentric layers 2300 around central location 2301. In this example, concentric layers 2300 comprises five concentric layers, which has central location 2301, layer 2321, layer 2322, layer 2323, and layer 2324. Each layer in concentric layers 2300 is thicker than the previous layer in concentric layers 2300. For example, layer 2322 is thicker than layer 2321. In this example, central location 2301 is the innermost layer and layer 2324 is the outermost layer in concentric layers 2300.

[0433] As depicted, a dashed line in a layer in a hexagonal shape extends through the center of beam spots. In this example, each of concentric layers 2300 has a hexagonal shaped dashed line. The dashed lines represents a path of the laser beam through each of the layers. Each layer in these concentric layers can be also referred to as a zone or sector around central location 2301.

[0434] In this example, overlap 2370 between locations in adjacent layers decreases during movement of the laser beam in performing hexagonal scan 2231. In this depicted example, the overlap 2370 decreases at each layer in con-

centric layers 2300. With this example, as the layers in concentric layers 2300 become thicker, overlap 2370 decreases.

[0435] In this example, overlap 2370 for a selected layer is the overlap between the selected layer and another layer in hexagonal scan 2231. The layer can be a prior layer or a subsequent layer.

[0436] For example, overlap 2370 for layer 2322 has width 2360, which is the overlap between locations in layer 2322 and locations in layer 2321. In other words, the overlap 2370 in a current layer is the overlap between locations that form the current layer and locations in the prior layer that was previously scanned.

[0437] In another example, overlap 2370 can be with a current layer and a subsequent layer that will be scanned. For example, overlap 2370 for layer 2322 can be the overlap between locations in layer 2322 and locations in layer 2323. Overlap 2370 can reduce issues caused to vibrations at the source of the laser beam. For example, vibrations in a laser beam system can cause the laser beam to have jitter such that the laser beam does not hit the intended location at which the laser beam is directed or pointed. Overlap 2370 can increase the likelihood that the laser beam hits the object even with jitter in the laser beam.

[0438] For example, an object such as a satellite is at a first location. The laser beam directed to the first location may result in a miss because of the jitter in the laser beam. However, the overlap of the first location from a second location increases the probability that the satellite will be hit when the laser beam is directed at the second location. For example, the laser beam may miss the satellite while moving layer 2322. The laser beam may hit the satellite while moving along layer 2323 because of overlap 2370 between layer 2322 and layer 2323.

[0439] In this example, overlap 2370 for layer 2323 is the overlap between locations in layer 2323 and locations in layer 2322. In this example, the overlap has width 2361.

[0440] As depicted, width 2360 of the overlap for layer 2322 is greater than width 2361 for layer 2323. In this example, the overlap decreases as the scan progresses outwards through concentric layers 2300 in hexagonal scan 2231.

[0441] In this example, overlap can be referred to as a path overlap and can be used to increase the probability of detecting an object such as a satellite while minimizing the time to scan an area such as a hexagonal shape or other areas with other shapes. In these examples, increasing overlap between the layers or sections in a scan increases the probability that an object will be detected in those layers or sections. In these examples, the probability of detecting the object is dependent in part on overlap of a layer with an adjacent layer.

[0442] With reference to FIG. 24, an illustration of a hexagon scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan 2241 has adjustments to beam divergence that change during performance of hexagonal scan 2241. In this example, hexagonal scan 2241 is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved to perform hexagonal scan 2031.

[0443] For example, hexagonal scan 2241 starts at central location 2401 and moves from location to location in layers that form concentric layers 2400.

[0444] As depicted, these beam spots are organized as concentric layers **2300** around central location **2301**. In this example, concentric layers **2400** comprises five concentric layers. Central location **2301** is the first layer. The other four layers are layer **2421**, layer **2422**, layer **2423**, and layer **2424**. Each layer in concentric layers **2300** is thicker than the previous layer in concentric layers **2300**. For example, layer **2322** is thicker than layer **2321**. In this example, central location **2401** is the innermost layer and layer **2424** is the outermost layer in concentric layers **2400**.

[0445] In this example, beam divergence increases from layer to layer in concentric layers **2400**. As a result, the size of beam spot in a plane increases from layer to layer in concentric layers **2400** during the performance of hexagonal scan **2241**.

[0446] For example, a low irradiance laser beam is harder to detect than a high irradiance laser beam. Also increasing the beam divergence (i.e., larger spot size) of a laser beam reduces the irradiance of the laser beam. As a result, hitting an object such as a satellite becomes more difficult as the beam spot size of the laser beam increases from changing the beam divergence. Increasing the spot size through increased beam divergence enables covering more of the scan area as compared to a smaller spot size. As a result, scan time can decrease as the beam divergence increases for a scan area.

[0447] A limited amount of time can be present for completing a scan of an area. With this limitation in mind, it is desirable to maximize the probability that the laser beam will hit the target and the target will detect the laser beam. In these examples, the object is expected to be near the center of the area being scanned. As a result, a higher laser beam irradiance is used when scanning the center of the area as compared to outer portions of the area. As a result, the beam spot should be small (i.e., low beam divergence). A small beam divergence takes more time to scan as compared to a larger beam divergence.

[0448] This changing to the beam divergence can be performed to decrease the time needed to scan the area. In these examples, the probability that the object is located near the edge of the area being scanned is lower as compared to the center of the area being scanned. As a result, beam divergence can be increased to increase beam spot size at the edge of the area to reduce the scan time for scanning area at portions of the area farther away from the center. As a result, increasing the beam divergence can reduce scan time. This saved scan time can be used to scan near the center. In other words, resources are shifted away from the portions of the area being scanned that are less likely to contain the object to scan the portions where the object is more likely to be present. The use of the increased beam divergence results in the beam being less likely to hit the object and the object being less likely to detect the laser beam when the object is located on the edge of the area being scanned. This lower probability of hitting an object is made up by the increased probability of hitting the object at the center of the area being scanned.

[0449] In another example, if a required probability of hitting and detection by the object is specified, the time for scanning can be traded for the probability to minimize scan time.

[0450] Next in FIG. 25, an illustration of a hexagon scan with decreasing dwell time is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan **2251** has adjustments to dwell time that change during

performance of hexagonal scan **2251**. In this example, hexagonal scan **2231** is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved from location to location to perform hexagonal scan **2251**.

[0451] For example, hexagonal scan **2241** starts at central location **2401** and moves from location to location in layers that form concentric layers **2500**.

[0452] As depicted, these beam spots are organized as concentric layers **2500** around central location **2501**. In this example, concentric layers **2500** comprises five concentric layers. Central location **2501** is the first layer. The other four layers are layer **2521**, layer **2522**, layer **2523**, and layer **2524**. In this example, each layer in concentric layers **2500** has a dwell time that is less than the dwell time in a previous layer in concentric layers **2500**.

[0453] In this illustrative example, the dwell time increases as hexagonal scan **2251** progresses. More specifically, the dwell time for the laser beam decreases at each layer in concentric layers **2500**. For example, the dwell time used for layer **2521** is greater than the dwell time for layer **2522**.

[0454] In these illustrative examples, increased dwell time increases the probability that an object such as a satellite can be detected in the search of an area such as a search area. For example, the amount of time to aim a beam at an object is dwell time. As the dwell time increases, the probability that the object will be hit by the laser beam and that the laser beam will be detected by the target increases. Increasing dwell time results in increasing the scan time.

[0455] In the illustrative example a set amount of time can be present to complete a scan of an area. Further, it is desirable to maximize the probability that an object such as a satellite will be hit by the laser beam and that the satellite will detect the laser beam. With this example, the satellite is expected to be near the center of the area being scanned. As a result, a laser dwell time is used when scanning near the center. However, with limited scan time, the dwell time can be reduced in other portions of the area being scanned to avoid increasing the scan time from increasing the dwell time. In this depicted example, the satellite is not expected to be near the edge of the area. As a result, the dwell time can be decreased at the edge. This reduction in scan time for this portion can offset the increase in scan time near the center of the area. In other words, resources (dwell time) are shifted away from portions of the scan area that are less likely to contain the satellite to portions of the area where the satellite is more likely to be present. The reduction of the dwell time results in reducing the likelihood that the laser beam will hit and be detected by a satellite located on the edge of the area. This reduction in probability is offset by increasing the probability of the laser beam hitting and being detected by the satellite close to the center of the area being searched, where the satellite is expected to be located.

[0456] In this illustrative example, greater dwell times can be used in areas in which the object is more likely to be found as compared to areas in which the object is less likely to be found. In this manner, a hexagonal scan can be performed without increasing the amount of scan time.

[0457] The illustration of changing scan parameters in FIGS. 22-25 for a hexagonal scan is provided as one example and not meant to limit the manner in which other illustrative examples can be implemented. For example, although the scan parameters change at each layer, the scan

parameters can change while scanning is performed within a layer. For example, scan parameters can change within a layer in the concentric layers. For example, a portion or segment of a layer can have one overlap while another portion or segment of the same layer can have a different overlap.

[0458] Further, one or more scan parameters can be changed during a hexagonal scan in addition to the scan parameters illustrated in these hexagonal scans. In other illustrative examples, other types of electromagnetic beams can be used in addition to the laser beam. For example, the electromagnetic beam used in the scans can be selected from a group comprising a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam. Further, these type of scans can also be used in receiving electromagnetic signals from an electromagnetic signal source.

[0459] Turning to FIG. 26, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. 26 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 2014 in computer system 2012 in FIG. 20.

[0460] The process begins by directing the electromagnetic beam at a central location in a search area in which an object is expected to be located (operation 2600). The process moves the electromagnetic beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the object is at the central location, wherein the next location becomes a current location for the electromagnetic beam (operation 2602).

[0461] The process adjusts a number of scan parameters during a movement of the electromagnetic beam to scan the search area (operation 2604). The process continues to move the electromagnetic beam from the current location to the next location that is a nearest neighbor to the current location in response to not receiving the confirmation that the object has received the electromagnetic beam (operation 2606). The process terminates thereafter.

[0462] Turning to FIG. 27, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. 27 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 2014 in computer system 2012 in FIG. 20.

[0463] The process directs the laser beam at a central location in a search area in which a satellite is expected to be located (operation 2700). The process moves the laser beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location, wherein the next location becomes a current location for the laser beam (operation 2702).

[0464] The process adjusts a number of scan parameters during a movement of the laser beam to scan the search area (operation 2704). In operation 2704, the number of scan

parameters can be changed during every movement of the laser beam or during one or more movements of the laser beam to the scan search area 2081. For example, the number of scan parameters can be changed from location to location. The adjustment to the number of scan parameters is made to efficiently search for a satellite. In some cases, the scan parameters can be changed between some locations and not all of the locations.

[0465] The process continues to move the laser beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the satellite has received the laser beam (operation 2706). The process terminates thereafter.

[0466] Next in FIG. 28, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 2704 in FIG. 27.

[0467] The process decreases an overlap during the movement of the laser beam to scan the search area (operation 2800). The process terminates thereafter.

[0468] With reference now to FIG. 29, an illustration of a flowchart of a process for decreasing overlap is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 2800 in FIG. 28.

[0469] The process decreases the overlap at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the overlap at locations in a layer is uniform (operation 2900). The process terminates thereafter.

[0470] Next in FIG. 30, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 2704 in FIG. 27.

[0471] The process increases a beam divergence of the laser beam during the movement of the laser beam to scan the search area (operation 3000). The process terminates thereafter.

[0472] With reference now to FIG. 31, an illustration of a flowchart of a process for increasing beam divergence is depicted in accordance with an illustrative embodiment. Process in this flowchart is an example of an implementation for operation 3000 in FIG. 30.

[0473] The process increases the beam divergence of the laser beam at each layer during the movement of the laser beam to scan the search area, wherein the beam divergence of the laser beam at locations in a layer is uniform (operation 3100). The process terminates thereafter.

[0474] Turning next to in FIG. 32, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 2704 in FIG. 27.

[0475] The process decreases a dwell time for the laser beam during the movement of the laser beam to scan the search area (operation 3200). The process terminates thereafter.

[0476] Next in FIG. 33, an illustration of a flowchart of a process for decreasing dwell time is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 3200 in FIG. 32.

[0477] The process decreases the dwell time for the laser beam at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the dwell time of the laser beam at locations in a layer is uniform (operation 3300). The process terminates thereafter.

[0478] With reference next to FIG. 34, an illustration of a flowchart of a process for receiving electromagnetic signals is depicted in accordance with an illustrative embodiment. The process in FIG. 34 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 2114 in computer system 2112 in FIG. 21.

[0479] The process moves a field of view of an electromagnetic signal receiver to a central location in a search area in which an electromagnetic signal source is expected to be located (operation 3400). The process moves the field of view to a next location that is a nearest neighbor to the central location in response to not detecting electromagnetic signals from the central location, wherein the next location becomes a current location for the field of view (operation 3402).

[0480] The process adjusts a number of scan parameters during a movement of the field of view to scan the search area (operation 3404). The process continues to move the field of view from the current location to the next location that is the nearest neighbor to the current location in response to not detecting electromagnetic signals (operation 3406). The process terminates thereafter.

[0481] The flowcharts and block diagrams in the different depicted examples in FIGS. 26-34 illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative example. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0482] In some alternative implementations of an illustrative example, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0483] With reference now to FIG. 35, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In

this illustrative example, electromagnetic signal environment 3500 includes components that can be implemented in hardware such as the hardware in satellite 101 and satellite 102 in FIG. 1.

[0484] In this example, electromagnetic beam transmission system 3502 is an example of an implementation of electromagnetic beam transmission system 202 in FIG. 2. The components can be implemented using components in electromagnetic beam transmission system 202 in electromagnetic signal environment 200 in FIG. 2.

[0485] In this illustrative example, electromagnetic beam transmission system 3502 can point the transmission of electromagnetic beam 3503 at object 3593. In this example, object 3593 can be electromagnetic beam receiver 3504. Object 3593 can also be platform 3505 with which electromagnetic beam receiver 3504 is connected in this example.

[0486] In this illustrative example, electromagnetic beam transmission system 3502 comprises electromagnetic beam system 3520 and controller 3514. In this example, controller 3514 is located in computer system 3512. As depicted, computer system 3512 is also part of electromagnetic beam transmission system 3502.

[0487] Electromagnetic beam system 3520 is a physical hardware system. This hardware system is configured to transmit electromagnetic beam 3503.

[0488] Controller 3514 can be implemented in a similar manner as controller 214 in FIG. 2 in which program instructions 3518 can be used to implement controller 3514 that are executed by a number of processor units 3516 in computer system 3512. In this example, controller 214 includes processes similar to those in controller 214 in FIG. 2 but also includes additional processes for controlling the manner in which a scan is performed. Program instructions 3518, the number of processor units 3516, and computer system 3512 can be implemented in a similar manner to program instructions 218, processor units 216, and computer system 212 in FIG. 2.

[0489] In this illustrative example, controller 3514 controls electromagnetic beam transmission system 3502 to direct electromagnetic beam 3503 at location 3522 nearest to maximum 3523 of uncertainty area 3581 in which object 293 is expected to be located. In other words, uncertainty area 3581 is an area in which object 3593 is believed to be present. However, object 3593 may not actually be in uncertainty area 3581. In some cases, uncertainty area 3581 can be selected as an area for searching with the hope of locating object 3593.

[0490] Further in this example, maximum 3523 represents a probability that object 3593 is at a location (beam spot) covered by electromagnetic beam system 3520. Maximum 3523 does not need to be 100 percent but can be some lower percentage.

[0491] As depicted, electromagnetic beam 3503 has beam spot 3561. In this example, beam spot 3561 is a diameter of electromagnetic beam 203 at a location in uncertainty area 3581. In this example, beam spots can correspond to locations in uncertainty area 3581. For example, location 3522 in uncertainty area 3581 can have a size and shape that corresponds to beam spot 3561 when the electromagnetic beam 3503 is directed at location 3522.

[0492] Location 3522 nearest to maximum 3523 of uncertainty area 3581 can be determined using a probability density function (PDF) that shows what location is likely to be closest to maximum 3523.

[0493] In this example, controller 3514 controls electromagnetic beam system 3520 to move electromagnetic beam 3503 from location 3522 to next location 3524 nearest to maximum 3523 of uncertainty area 3581 in response to not receiving confirmation 3527 that object 3593 such as electromagnetic beam receiver 3504 is at location 3522. In this example, next location 3524 becomes current location 3525 for electromagnetic beam 3503.

[0494] Further in this example, controller 3514 adjusts a number of scan parameters 3570 during a movement of electromagnetic beam 3503 to scan uncertainty area 3581. In this illustrative example, the number of scan parameters 3570 can be adjusted by controller 3514 controlling electromagnetic beam system 3520. In this illustrative example, the number of scan parameters 3570 can be adjusted to increase the likelihood that electromagnetic beam 3503 hits object 3593 in uncertainty area 3581.

[0495] Controller 3514 controls electromagnetic beam system 3520 to continue to move electromagnetic beam 3503 from current location 3525 to next location 3524 nearest to maximum 3523 of uncertainty area 3581 from current location 3525 in response to not receiving a confirmation 3527 that electromagnetic beam 3503 has encountered object 3593, such as electromagnetic beam receiver 3504 receiving electromagnetic beam 3503. This type of movement of electromagnetic beam 3503 is nearest to maximum scan 3540. When maximum 3523 of uncertainty area 3581 is the center of uncertainty area 3581, nearest to maximum scan 3540 is nearest to center scan 3597. This is an example of an implementation for nearest to maximum scan 3540 in which maximum 3523 of uncertainty area 3581 is the center of uncertainty area 3581.

[0496] In one illustrative example, electromagnetic beam 3503 can take the form of laser beam 3533. Further, laser beam 3533 can be selected from a group comprising a continuous laser beam and a pulsed laser beam. Electromagnetic beam system 3520 can be laser beam system 3530 and platform 3505 can take the form of satellite 3538. In this example, electromagnetic beam transmission system 3502 is laser beam transmission system 3511.

[0497] In this example, controller 3514 controls laser beam system 3530 to direct laser beam 3533 at location 3522 nearest to maximum 3523 of uncertainty area 3581 in which satellite 3538 is expected to be located. Controller 3514 also controls laser beam system 3530 to move laser beam 3533 from location 3522 to next location 3524 nearest to maximum 3523 of uncertainty area 3581 in response to not receiving confirmation 3527 that satellite 3538 is at location 3522. In this example, next location 3524 becomes current location 3525 for laser beam 3533.

[0498] Further, controller 3514 adjusts a number of scan parameters 3570 during a movement of laser beam 3533 to scan uncertainty area 3581. In this illustrative example, the number of scan parameters 3570 can be adjusted to increase the likelihood that laser beam 3533 hits satellite 3538 in uncertainty area 3581. The number of scan parameters 3570 can be selected from at least one of overlap 3571, beam divergence 3572, dwell time 3573, or other suitable scan parameters.

[0499] In adjusting the number of scan parameters 3570, controller 3514 decreases overlap 3571 during the movement of laser beam 3533 to scan uncertainty area 3581. With this example, maximum 3523 of uncertainty area 3581 is a center of uncertainty area 3581. Further, overlap 3571 at

locations that have a same distance from the maximum of the uncertainty area is uniform. In other words, each location in the locations having the same distance from the center of uncertainty area 3581 have the same overlap. Locations having the same distance from the center of uncertainty area 3581 form a group of locations. Each group of locations having longer distance from the center of uncertainty area 3581 have a greater overlap.

[0500] Further, in adjusting the number of scan parameters 3570, controller 3514 increases beam divergence 3572 of laser beam 3533 during the movement of laser beam 3533 to scan uncertainty area 3581. In this example, maximum 3523 of uncertainty area 3581 is a center of uncertainty area 3581. Further with this example, beam divergence 3572 of laser beam 3533 at locations that have a same distance from maximum 3523 of uncertainty area 3581 is uniform.

[0501] In adjusting the number of scan parameters 3570, controller 3514 decreases dwell time 3573 for laser beam 3533 during movement of laser beam 3533 to scan uncertainty area 3581. With this example, maximum 3523 of uncertainty area 3581 is a center of uncertainty area 3581. Dwell time 3573 of laser beam 3533 at locations that have a same distance from the maximum 3523 of uncertainty area 3581 is uniform.

[0502] Controller 3514 controls laser beam system 3530 to continue to move laser beam 3533 from current location 3525 to next location 3524 nearest to maximum 3523 of uncertainty area 3581 from current location 3525 in response to not receiving confirmation 3527 that satellite 3538 has received laser beam 3533. The moving or directing of laser beam 3533 can also be referred to as pointing laser beam 3533. Further, laser beam 3533 can be selected from one of unidirectional communications and bidirectional communications.

[0503] In this example, confirmation 3527 can be received from satellite 3538. For example, satellite 3538 sends a return laser beam at the same angle as the incoming laser beam.

[0504] In this example, the movement controlled by controller 3514 is nearest to maximum scan 3540 such as nearest to maximum hexagonal scan 3541. With this example, uncertainty area 3581 can be in a shape of hexagon 3591 for nearest to maximum hexagonal scan 3541. Further, controller 3514 can control the movement of laser beam 3533 to change from nearest to maximum scan 3540 to nearest neighbor scan 3542. This type of scan in which the scanning changes from nearest to maximum scan 3540 to nearest neighbor scan 3542 is hybrid scan 263.

[0505] For example, controller 3514 moves laser beam 3533 to neighbor location 3543 of nearest neighbor 3544 in response to time 3548 for moving laser beam 3533 from current location 3525 to next location 3524 using location 3522 nearest to maximum 3523 of uncertainty area 3581 being greater than threshold 3547. In this example, next location 3524 becomes current location 3525 for future movements.

[0506] In this case, threshold 3547 can be selected as the time for moving laser beam 3533 from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time.

[0507] Further in this example, controller 3514 continues to move laser beam 3533 from current location 3525 to subsequent neighbor location 3545 of nearest neighbor 3544 from current location 3525 in response to time 3548 for

moving laser beam **3533** from current location to next location **3524** using location **3522** nearest to maximum **3523** of uncertainty area **3581** being greater than threshold **3547** and in response to not receiving confirmation **3527** that satellite **3538** has received laser beam **3533**.

[**0508**] As a result, controller **3514** changes from using nearest to maximum scan **3540** to nearest neighbor scan **3542**. This type of hybrid scan can provide a faster location of satellite **3538** as compared to just using nearest to maximum scan **3540**.

[**0509**] In moving laser beam **3533** to neighbor location **3543** of nearest neighbor **3544** and continuing to move laser beam **3533** from current location **3525** to subsequent neighbor location **3545** of nearest neighbor **3544** from current location **3525** is part of a nearest neighbor scan **3542** selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, a hexagonal scan, and a raster scan.

[**0510**] In response to receiving confirmation **3527**, controller **3514** establishes communications with satellite **3538**. The communication is selected from one of unidirectional communications and bidirectional communications.

[**0511**] In one illustrative example, one or more technical solutions are present that overcome a technical problem with pointing an electromagnetic beam, such as a laser, at a receiver. As a result, one or more illustrative examples enable scanning an area such as an uncertainty area in an efficient manner. The number of scan parameters can be adjusted during the scanning of the uncertainty area in a manner that increases the likelihood of hitting an object. In some examples, a hybrid scan can be used.

[**0512**] Computer system **3512** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware, or a combination thereof. As a result, computer system **3512** operates as a special purpose computer system in which controller **3514** in computer system **3512** enables adjusting scan parameters such that locating an object can be performed more quickly as compared to current techniques. Controller **3514** transforms computer system **3512** into a special purpose computer system as compared to currently available general computer systems that do not have controller **3514**.

[**0513**] The illustration of electromagnetic signal environment **3500** in FIG. 35 is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[**0514**] For example, electromagnetic beam **3503** has been described as being laser beam **3533**. Electromagnetic beam **3503** can take other forms in other illustrative examples. For example, electromagnetic beam **3503** can be selected from a group comprising laser beam **3533**, a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam.

[**0515**] As another example, platform **3505** can take a number of different forms in addition to satellite **3538**. For example, electromagnetic beam receiver **3504** can be located in platform **3505** selected from a group comprising a mobile platform, a stationary platform, a land-based struc-

ture, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[**0516**] As another example, uncertainty area **3581** can take other shapes in addition to hexagon **3591**. For example, uncertainty area **3581** can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape. Controller **3514** can control one or more electromagnetic beam systems in addition to or in place of electromagnetic beam system **3520**. Further, the system can be used with an electromagnetic signal receiver system as described below with respect to FIG. 36.

[**0517**] In these examples, pointing electromagnetic signal receiver at an electromagnetic signal source can also take more time than desired and is more challenging than desired.

[**0518**] With reference now to FIG. 36, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment **3600** includes components that can be implemented in hardware such as the hardware shown in satellite **120** and receiver **122** and telescope **123** in FIG. 1.

[**0519**] In the illustrative example, electromagnetic signal receiver system **3601** in electromagnetic signal environment **3600** can be pointed to receive electromagnetic signals **3603** from electromagnetic signal source **3604**. In this example, electromagnetic signal receiver system **3601** comprises electromagnetic signal receiver **3602** and controller **3614**. In this example, controller **3614** is located in computer system **3612**. As depicted, computer system **3612** is part of electromagnetic signal receiver system **3601** in this example. In this example, these components can be examples of components in electromagnetic signal receiver system **301** in FIG. 3. The components can be implemented using components in electromagnetic signal receiver system **301** in FIG. 3.

[**0520**] In this illustrative example, electromagnetic signal source **3604** generates electromagnetic signals **3603**. Electromagnetic signals **3603** can take a number of different forms. For example, electromagnetic signals **303** can be a beam, collimated beam, omnidirectional signals, directional signals, or other types of radiation patterns for forms. Electromagnetic signals **3603** can be selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, ultraviolet light signals, or other types of electromagnetic signals.

[**0521**] Electromagnetic signal source **3604** can take a number of different forms. For example, electromagnetic signal source **3604** can be a platform selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a

satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[0522] Electromagnetic signal receiver 3602 is a physical hardware system that can receive electromagnetic signals 3603. Electromagnetic signal receiver 3602 has field of view 3621. In this illustrative example, hardware such as an antenna, radio receiver, photo detector, or other device that can detect electromagnetic signals 3603 that are in field of view 3621. This hardware is unable to detect or use electromagnetic signals 3603 outside the field of view 3621. The hardware can include receiver 3683. Receiver 3683 can be implemented using a receiver such as a photodetector, a photodiode system, a phase array antenna, focal plane array (FPA), cell (QC), or other suitable types of hardware.

[0523] In another illustrative example, electromagnetic signal receiver 3602 can include telescope 3682. Telescope 3682 is a hardware component collecting incoming electromagnetic signals onto a detector in receiver 3683.

[0524] In this illustrative example, field of view (FOV) 3621 is the view that electromagnetic signal receiver 3602 has to see or receive electromagnetic signals 3603.

[0525] In some illustrative examples, the size of field of view 3621 can be controlled. Field of view 3621 can have a size that enables detecting electromagnetic signals 3603. For example, the time for nearest to maximum scan 3640 to locate electromagnetic signal source 3604 is faster than current techniques such as those that use a continuous file scan, a segment scan, or raster scan. However, actually detecting electromagnetic signals 3603 may be difficult with electromagnetic signals 3603 being too weak for detection with the size of field of view 3621. For example, the aperture or coping defining the field of view for a receiver may pick up signals from other sources for noises in addition to the signals from the desired source. As a result, the receiver may struggle to identify and isolate electromagnetic signals 3603 from the surrounding noise. As a result, reducing or narrowing field of view 3621 can be performed to reduce issues with noise. In other words, size of field of view 3621 can be adjusted to increase the signal-to-noise ratio.

[0526] In another example, the scan time becomes slower as field of view 3621 is decreased. At some point, field of view 3621 may be able to easily detect electromagnetic signals 3603. However, the amount of scan time may be much slower than desired and may be slower than current techniques.

[0527] The size of field of view 3621 can be selected such that electromagnetic signals 3603 can be just barely detectable. In other words, these electromagnetic signals can be detected over noise that may be present. With this selection of the size for field of view 3621, nearest to maximum scan 3640 can be performed within a desired amount of time such as less than techniques that use a continuous scan based on a nearest neighbor.

[0528] Controller 3614 can be implemented in a similar manner as controller 314 in FIG. 3 in which program instructions 3618 can be used to implement controller 3614 that are executed by a number of processor units 3616 in computer system 3612. In this example, controller 3614 includes processes similar to those in controller 314 in FIG. 3 but also includes additional processes for controlling the manner in which a scan is performed to detect electromagnetic signals 3603. Program instructions 3618, the number of processor units 3616, and computer system 3612 can be

implemented in a similar manner to program instructions 318, processor units 316, and computer system 312 in FIG. 3.

[0529] Controller 3614 is configured to control the operation of electromagnetic signal receiver 3602. In this illustrative example, controller 3614 controls electromagnetic signal receiver 3602 to move field of view 3621 of electromagnetic signal receiver 3602 to location 3622 nearest to maximum 3623 of uncertainty area 3681 in which an electromagnetic signal source 3604 is expected to be located. This moving of field of view 3621 can also be referred to as pointing field of view 3621.

[0530] Further, in this example, controller 3614 moves field of view 3621 of electromagnetic signal receiver 3602 from location 3622 to next location 3624 nearest to maximum 3623 of uncertainty area 3681 in response to not detecting electromagnetic signals 3603 from electromagnetic signal source 3604 at location 3622. In this example, next location 3624 becomes current location 3625 for field of view 3621.

[0531] Controller 3614 adjusts a number of scan parameters 3670 during a movement of field of view 3621 to scan uncertainty area 3681. The number of scan parameters 3670 changes during scanning of uncertainty area 3681. In other words, the number of scan parameters 3670 does not remain fixed during the entire scan.

[0532] The number of scan parameters 3670 can be selected from at least one of overlap 3671, beam divergence 3672, dwell time 3673, or other suitable scan parameters. In this illustrative example, the number of scan parameters 3670 can be adjusted to increase the likelihood that electromagnetic signals 3603 from electromagnetic signal source 3604 are detected.

[0533] In this illustrative example, the number of scan parameters 3670 can be changed during movement of field of view 3621 using the same type of adjustments as described with respect to controller 3514 adjusting scan parameters 3570 while controlling laser beam system 3530 to move laser beam 3533 to scan uncertainty area 3581 in FIG. 35.

[0534] Controller 3614 continues to move field of view 3621 from current location 3625 to next location 3624 nearest to maximum 3623 of uncertainty area 3681 from current location 3625 in response to not detecting electromagnetic signals 3603 from electromagnetic signal source 3604. This type of movement of the field of view 3621 is a nearest to maximum scan 3640. This scan can be nearest to maximum hexagonal scan 3641 with uncertainty area 3681. In this example, uncertainty area 3681 can be in a shape of hexagon 3691. In other examples, uncertainty area 3681 can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape in addition to or in place of hexagon 3691.

[0535] Further, controller 3614 can change the manner in which field of view 3621 is moved. In this example, controller 3614 can begin with nearest to maximum scan 3640 and change to nearest neighbor scan 3642. This type of scan in which the scanning changes from nearest to maximum scan 3640 to nearest neighbor scan 3642 is referred to as hybrid scan 3663.

[0536] For example, controller 3614 moves field of view 3621 to neighbor location 3643 of nearest neighbor 3644 in response to time 3648 for moving field of view 3621 from current location 3625 to next location 3624 using location

3622 nearest to maximum **3623** of uncertainty area **3681** being greater than threshold **3647**. In this example, next location **3624** becomes current location **3625**.

[0537] Controller **3614** continues to move field of view **3621** from current location **3625** to subsequent neighbor location of nearest neighbor **3644** from current location **325** in response to time **3648** for moving field of view **3621** from current location **3625** to next location **3624** using location **3622** nearest to maximum **3623** of uncertainty area **3681** being greater than threshold **3647** and in response to not detecting electromagnetic signals **3603** from electromagnetic signal source **3604**.

[0538] In this case, threshold **3647** can be selected as the time for moving field of view **3621** from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time.

[0539] Also, moving field of view **3621** to neighbor location **3643** of nearest neighbor **3644** and continuing to move field of view **3621** from current location **3625** to subsequent neighbor location **3645** of nearest neighbor **3644** from current location **3625** is part of nearest neighbor scan **3642** in this example. This nearest neighbor scan can be selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, a hexagonal scan, and a raster scan.

[0540] In this illustrative example, controller **3614** can detect electromagnetic signals **3603** from electromagnetic signal source **3604** in response to detecting selected electromagnetic signals that are greater than a noise level in field of view **3621**. In response to detecting electromagnetic signals **3603**, controller **3614** can establish communications with electromagnetic signal source **3604**. The communications are selected from one of unidirectional communications and bidirectional communications. In the illustrative example, the communications that are unidirectional from electromagnetic signal source **3604** to electromagnetic signal receiver **3602** does not necessarily require electromagnetic signal source **3604** to know that electromagnetic signals **3603** are being received by electromagnetic signal receiver **3602**.

[0541] The illustration of electromagnetic signal environment **3600** in FIG. 36 is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0542] For example, electromagnetic signal receiver system **3601** can be located on a platform. The platform can be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0543] In another illustrative example, controller **3614** can be located in a separate platform or location from electromagnetic signal receiver system **3601**. Additionally, electro-

magnetic signal receiver system **3601** may be used with an electromagnetic signal transmission system such as electromagnetic beam transmission system **3502** in FIG. 35.

[0544] In yet another illustrative example, controller **3614** can control one or more electromagnetic signal receiver systems in addition to or in place of electromagnetic signal receiver system **3601**.

[0545] With reference next to FIG. 37, an illustration of scans performed using scan parameters that are adjusted during the scanning of an uncertainty area is depicted in accordance with an illustrative embodiment. In this illustrative example, scans **3700** result from applying changes to scan parameters illustrated in spiral scans **3701** to nearest to center scan hexagonal **3702** and hybrid scan **3703**. Nearest to center scan hexagonal **3702** is an example of an implementation for nearest to maximum hexagonal scan **3541** in FIG. 35 in which maximum **3523** of uncertainty area **3581** is the center of uncertainty area **3581**. Hybrid scan **3703** is an example of an implementation for hybrid scan **3563** in FIG. 35. In this example, hybrid scan **3703** has a hexagonal shape.

[0546] As depicted, spiral scans **3701** include spiral scan **3721**, spiral scan **3722**, and spiral scan **3723**. These spiral scans provide a visual illustration of adjustments to scan parameters that occur during the performance of these spiral scans. In this example, spiral scans **3701** have been selected because the scans provide a clear visualization of changes to scan parameters.

[0547] In this example, these spiral scans include illustrative adjustments to overlap **3711**, beam divergence **3712**, and dwell time **3713**. As depicted, overlap **3711** decreases as spiral scan **3721** progresses. Further in this example, beam divergence **3712** increases as spiral scan **2222** progresses. Further in this example, dwell time **2213** decreases as spiral scan **2223** progresses.

[0548] In this example, nearest to center scan **3731** is nearest to center scan hexagonal **3702** with adjustments to overlap **3711**. In this example, overlap **3711** decreases as nearest to center scan **3731** progresses. Nearest to center scan **3732** is nearest to center scan hexagonal **3702** with adjustments to beam divergence **3712**. In this example, beam divergence **3712** increases as nearest to center scan **3732** progresses. Further, nearest to center scan **3733** is nearest to center scan hexagonal **3702** with adjustments to dwell time **3713**. In this example, dwell time **3713** increases as nearest to center scan **3732** progresses.

[0549] Also in this example, hybrid scan **3734** is hybrid scan **3703** with adjustments to overlap **3711**. As depicted, overlap **3711** decreases as hybrid scan **3703** progresses. Hybrid scan **3736** is hybrid scan **3703** with adjustments to beam divergence **3712**. In this example, beam divergence **3712** increases as hybrid scan **3736** progresses. In this illustrative example, hybrid scan **3736** is hybrid scan **3703** with adjustments to dwell time **3723**. In this example, dwell time **3723** increases as hybrid scan **3736** progresses.

[0550] Turning now to FIG. 38, an illustration of a nearest to center scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this example, center **3800** of the maximum of the uncertainty area **3801** is scanned using nearest to center scan **3731**. Each circle in FIG. 38 represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3731**.

[0551] Further in this example, uncertainty area **3801** has a circular shape. In this example, nearest to center scan **3731** is a hexagonal scan that scans the area within the circular shape of uncertainty area **3801**. Also, in this illustrative example, nearest to center scan **3731** includes locations that scans regions outside of uncertainty area **3801** to ensure that all of uncertainty area **3801** is scanned in these examples.

[0552] In this example, overlap **3870** for nearest to center scan **3731** decreases as the scan progresses. As depicted, overlap **3870** is greatest near center **3800** and is least at the perimeter of uncertainty area **3801**.

[0553] As depicted, the locations with the same distance from center **3800** form a layer. In this illustrative example, a layer is not necessarily a continuous layer. In other words, the layer can be comprised of segments based on the distance of locations from center **3800**.

[0554] In this example, center **3800** is a first layer that is the innermost layer. A second layer adjacent to center **3800** is formed by location **3851**, location **3852**, location **3853**, location **3854**, location **3855**, and location **3856**. These locations in the second layer all have the same distance from center **3800**.

[0555] A third layer adjacent to the second layer is formed by location **3821**, location **3822**, location **3823**, location **3824**, location **3825**, and location **3826**. These locations in the third layer are all the same distance from center **3800**.

[0556] In this example, overlap **3870** is uniform for locations in nearest to center scan **3731** that have the same distance from center **3800** of the uncertainty area. In other words, overlap **3870** for locations that have the same distance from center **3800** have the same overlap with locations in adjacent layers.

[0557] In these examples, overlap **3870** is between adjacent layers in nearest to center scan **3731**. In other words, an adjacent layer is a layer in which a location in the layer overlaps with a location in another layer that is next to the adjacent layer. This adjacent layer can be a prior layer that has already been scanned or a subsequent layer that will be scanned.

[0558] For example, location **3852** and location **3825** are in adjacent layers to each other. Overlap **3870** between these two locations in the adjacent layers has width **3897**. As another example, location **3831** is in a current layer while location **3832** is in an adjacent layer. In this example, overlap **3870** has width **3871**. Width **3871** is smaller than width **3897**.

[0559] In other words, the overlap **3870** between beam spots moving in nearest to center scan **3731** decreases as the scan progresses. The selection of overlap **3870** can be made in the same manner as overlap **2370** in FIG. 23.

[0560] Next in FIG. 39, an illustration of a nearest to center scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this example, center **3900** is the maximum of the uncertainty area **3901** scanned using nearest to center scan **3732**. Each circle in FIG. 39 represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3731**.

[0561] In this depicted example, uncertainty area **3901** has a circular shape. In this example, nearest to center scan **3732** is a hexagonal scan that scans the area within the circular shape of uncertainty area **3901**. Also, in this illustrative example, nearest to center scan **3732** includes locations that

scans regions outside of uncertainty area **3801** to ensure that all of uncertainty area **3901** is scanned in these examples.

[0562] In this illustrative example, beam divergence decreases as nearest to center scan **3732** progresses. As depicted, the beam divergence increases during movement of the laser beam to scan uncertainty area **3901**. In this example, the beam divergence at locations that have a same distance from center **3900** in uncertainty area **3901** one is uniform. In other words, the beam divergence is the same for locations with the same distance from center **3900**.

[0563] For example, location **3920** and location **3921** are the same distance from center **3900**. These two locations have the same beam divergence. Location **3922** and location **3923** both have the same distance from center **3900**. These two locations also have the same beam divergence with respect to each other.

[0564] With this example, location **3922** and location **3923** are scanned prior to location **3920** and location **3921**. In this example, location **3920** and location **3921** have larger beam divergence as compared to location **3922** and location **3923**. The selection of beam divergence can be made in the same manner as the selection of beam divergence in FIG. 24.

[0565] With reference now to FIG. 40, an illustration of a nearest to center scan with decreasing dwell time is depicted in accordance with an illustrative embodiment. In this illustrative example, center **4000** is the maximum of the uncertainty area **4001** scanned using nearest to center scan **3733**. Each circle in FIG. 40 represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3733**.

[0566] In this depicted example, uncertainty area **4001** has a circular shape. In this example, nearest to center scan **3733** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4001**. Also, in this illustrative example, nearest to center scan **3733** includes locations that scans regions outside of uncertainty area **4001** to ensure that all of uncertainty area **4001** is scanned in these examples.

[0567] In this illustrative example, the dwell time decreases as nearest to center scan **3733** progresses. Further, in this example, the dwell time between locations having a same distance from center **4000** is uniform. In other words, these locations have the same dwell time.

[0568] For example, location **4020** and location **4021** are the same distance from center **4000**. These two locations have the same dwell time. Location **4022** and location **4023** have the same distance from center **4000**. These two locations have the same dwell time.

[0569] In this example, location **4020** and location **4021** are scanned later in nearest to center scan **3733** as compared to location **4022** and location **4023**. Location **4020** and location **4021** are farther from center **4000** as compared to these other two locations. As a result, the likelihood that an object of interest is present is lower as compared to location **4022** and location **4023**. Thus, these two locations have a shorter dwell time as compared to location **4022** and location **4023**. The selection of dwell time can be made in the same manner as the selection of dwell time in FIG. 25.

[0570] In FIG. 41, an illustration of a hybrid scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this depicted example, center **4100** is the maximum of the uncertainty area **4101** scanned using hybrid scan **3734**. Each circle in FIG. 41 represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3734**.

[0571] In this depicted example, uncertainty area **4101** has a circular shape. In this example, hybrid scan **3734** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4101**. Also, in this illustrative example, hybrid scan **3734** includes scanning locations that have regions outside of uncertainty area **4101** to ensure that all of uncertainty area **4101** is scanned in these examples.

[0572] In this example, overlap **4170** for hybrid scan **3734** decreases as the scan progresses. As depicted, overlap **4170** is greatest near center **4100** and is least at the perimeter of uncertainty area **4101**.

[0573] In this example, overlap **4170** for locations in hybrid scan **3734** that have the same distance from center **4100** of the uncertainty area is uniform. In other words, the overlap between locations that have the same distance from center **4100** have the same overlap. In other words, overlap **4170** for locations that have the same distance from center **4100** have the same overlap with locations in adjacent layers.

[0574] Locations having the same distance from center **4100** form a layer in this example. For example, location **4120** and location **4122** have the same distance from center **4100** and are part of the same layer. As depicted, location **4123** and location **4124** both have the same distance from center **4100** and thus are part of the same layer. As with the example in FIG. 38, the overlap is between adjacent layers. The selection of overlap **4170** can be made in the same manner as overlap **2370** in FIG. 23.

[0575] With reference to FIG. 42, an illustration of a hybrid scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this illustrative example, center **4200** is the maximum of the uncertainty area **4201** scanned using hybrid scan **3735**. Each circle in FIG. 42 represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3735**.

[0576] In this depicted example, uncertainty area **4201** has a circular shape. In this example, hybrid scan **3735** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4201**. Also, in this illustrative example, hybrid scan **3735** includes locations that scans regions outside of uncertainty area **4201** to ensure that all of uncertainty area **4201** is scanned in these examples.

[0577] In this illustrative example, beam divergence decreases as hybrid scan **3735** progresses. As depicted, the beam divergence increases during movement of the laser beam to scan uncertainty area **4201**. In this example, the beam divergence at locations that have a same distance from center **4200** in uncertainty area **4201** is uniform. Thus, the beam divergence is the same for locations with the same distance from center **4100**.

[0578] For example, location **4120** and location **4121** are the same distance from center **4100**. These two locations have the same beam divergence. Location **3922** and location **3923** both have the same distance from center **3900**. These two locations have the same beam divergence with respect to each other.

[0579] With this example, location **4122** and location **4123** are scanned prior to location **4120** and location **4121**. In this example, location **4120** and location **4121** have larger beam divergence as compared to location **3922** and location **3923**. The selection of beam divergence can be made in the same manner as the selection of beam divergence in FIG. 24.

[0580] With reference now to FIG. 43, an illustration of a hybrid scan with decreasing dwell time is depicted in

accordance with an illustrative embodiment. In this illustrative example, center **4300** is the maximum of the uncertainty area **4301** scanned using hybrid scan **3736**. Each circle in FIG. 43 represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3735**.

[0581] In this example, uncertainty area **4301** has a circular shape. In this example, hybrid scan **3736** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4301**. Also, in this illustrative example, hybrid scan **3736** includes locations that scans regions outside of uncertainty area **4301** to ensure that all of uncertainty area **4301** is scanned in these examples.

[0582] In this illustrative example, the dwell time decreases as hybrid scan **3736** progresses. Further, in this example, the dwell time between locations having a same distance from center **4300** is uniform. These locations with the same distance have the same dwell time.

[0583] For example, location **4320** and location **4321** are the same distance from center **4300**. These two locations have the same dwell time. Location **4322** and location **4323** have the same distance from center **4300**. Thus, these two locations have the same dwell time.

[0584] In this example, location **4320** and location **4321** are scanned later in hybrid scan **3736** as compared to location **4322** and location **4323**. Location **4320** and location **4321** are farther from center **4300**. As a result, the likelihood that an object of interest is present is lower as compared to location **4022** and location **4023**. Thus, these two locations have a shorter dwell time as compared to location **4022** and location **4023**. The selection of dwell time can be made in the same manner as the selection of dwell time in FIG. 25.

[0585] The illustration of scans in FIGS. 37-43 has been presented for purposes of depicting an illustrative example. This illustration is not meant to limit the manner in which other illustrative examples can be implemented. For example, the uncertainty areas in these figures have been described as a hexagon. In other illustrative examples, other shapes can be used such as a circle, an octagon, or other shape with a radial symmetry.

[0586] Further, in performing the searches, the nearest to the center scans and hybrid scans can be further optimized in addition to changing a number of scan parameters during the movement of a laser beam. For example, locations in the scan identified as falling outside of the uncertainty area can be skipped.

[0587] Further, in other illustrative examples, other types of electromagnetic beams can be used in addition to the laser beam. For example, the electromagnetic beam used in the scans can be selected from a group comprising a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam. Further, these type of scans can also be used in receiving electromagnetic signals from an electromagnetic signal source.

[0588] Turning to FIG. 44, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. 44 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **3514** in computer system **3512** in FIG. 35.

[0589] The process directs the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located (operation 4400). The process moves the electromagnetic beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam (operation 4402).

[0590] The process adjusts a number of scan parameters during a movement of the electromagnetic beam to scan the uncertainty area (operation 4404). The process continues to move the electromagnetic beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the electromagnetic beam has encountered the object (operation 4406). The process terminates thereafter.

[0591] With reference next to FIG. 45, an illustration of a flowchart of a process for pointing a laser beam is depicted in accordance with an illustrative embodiment. The process in FIG. 45 can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller 3514 in computer system 3512 in FIG. 35.

[0592] The process directs the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located (operation 4500). In one illustrative example, the uncertainty area is a nearest to maximum hexagonal scan. The process moves the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam (operation 4502).

[0593] The process adjusts a number of scan parameters during a movement of the laser beam to scan the uncertainty area (operation 4504). The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the satellite has received the laser beam (operation 4506). The process terminates thereafter.

[0594] With reference next to FIG. 46, an illustration of a flowchart of a process for moving the laser beam is depicted in accordance with an illustrative embodiment.

[0595] The process in this flowchart is an example of additional operations that can be performed with operations in FIG. 45. In this example, the process can move the laser beam to perform a hybrid scan.

[0596] The process moves the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location (operation 4600). The process continues to move the laser beam from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to the time for moving the laser beam from the current location to the next location using the location nearest to the maximum

of the uncertainty area being greater than the threshold and in response to not receiving the confirmation that the satellite has received the laser beam (operation 4602). The process terminates thereafter. In this flowchart, operation 4504 from FIG. 45 continues to be performed with these operations to adjust a number of scan parameters.

[0597] With reference now to FIG. 47, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 4504 in FIG. 45.

[0598] The process decreases an overlap during the movement of the laser beam to scan the uncertainty area (operation 4700). The process terminates thereafter. In one illustrative example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the overlap at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0599] Turning to FIG. 48, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 4504 in FIG. 45.

[0600] The process increases a beam divergence of the laser beam during the movement of the laser beam to scan the uncertainty area (operation 4800). The process terminates thereafter. In one illustrative example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the beam divergence of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0601] Next in FIG. 49, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation 4504 in FIG. 45.

[0602] The process decreases a dwell time for the laser beam during movement of the laser beam to scan the uncertainty area (operation 4900). The process terminates thereafter. In this example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the dwell time of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0603] With reference now to FIG. 50, an illustration of a flowchart of a process for establishing communications is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an additional operation that can be performed with the operations in FIG. 45.

[0604] The process establishes communications with the satellite in response to receiving the confirmation (operation 5000). The process terminates thereafter.

[0605] The flowcharts and block diagrams in the different depicted embodiments in FIGS. 44-50 illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to

perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0606] In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0607] The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the embodiments in the form disclosed. The different illustrative examples describe components that perform actions or operations. In an illustrative embodiment, a component can be configured to perform the action or operation described. For example, the component can have a configuration or design for a structure that provides the component an ability to perform the action or operation that is described in the illustrative examples as being performed by the component. Further, to the extent that terms "includes", "including", "has", "contains", and variants thereof are used herein, such terms are intended to be inclusive in a manner similar to the term "comprises" as an open transition word without precluding any additional or other elements.

[0608] Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A laser beam transmission system comprising:
a laser beam system configured to transmit a laser beam; and
a controller configured to control the laser beam system to:
direct the laser beam at a central location in a search area in which a satellite is expected to be located; move the laser beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location, wherein the next location becomes a current location for the laser beam;
adjust a number of scan parameters during a movement of the laser beam to scan the search area; and
continue to move the laser beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the satellite has received the laser beam.

2. The laser beam transmission system of claim 1, wherein in adjusting the number of scan parameters, the controller is configured to:

decrease an overlap during the movement of the laser beam to scan the search area.

3. The laser beam transmission system of claim 2, wherein in decreasing the overlap, the controller is configured to:
decrease the overlap at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the overlap at locations in a layer is uniform.

4. The laser beam transmission system of claim 1, wherein in adjusting the number of scan parameters, the controller is configured to:
increase a beam divergence of the laser beam during the movement of the laser beam to scan the search area.

5. The laser beam transmission system of claim 4, wherein in increasing the beam divergence, the controller is configured to:
increase the beam divergence of the laser beam at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the beam divergence of the laser beam at locations in a layer is uniform.

6. The laser beam transmission system of claim 1, wherein in adjusting the number of scan parameters, the controller is configured to:
decrease a dwell time for the laser beam during the movement of the laser beam to scan the search area.

7. The laser beam transmission system of claim 6, wherein in decreasing the dwell time, the controller is configured to:
decrease the dwell time for the laser beam at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the dwell time of the laser beam at locations in a layer is uniform.

8. The laser beam transmission system of claim 1, wherein the movement of the laser beam to scan the search area is in a form of a nearest neighbor hexagonal scan.

9. The laser beam transmission system of claim 1, wherein the controller is configured to:
establish communications with the satellite in response to receiving the confirmation.

10. The laser beam transmission system of claim 9, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

11. The laser beam transmission system of claim 1, wherein the laser beam is selected from a group comprising a continuous laser beam and a pulsed laser beam.

12. The laser beam transmission system of claim 1, wherein the number of scan parameters is selected from at least one of an overlap, a beam divergence, or a dwell time.

13. An electromagnetic beam transmission system comprising:
an electromagnetic beam system configured to transmit an electromagnetic beam; and
a controller configured to control the electromagnetic beam system to:

direct the electromagnetic beam at a central location in a search area in which an object is expected to be located; move the electromagnetic beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the object is at the

central location, wherein the next location becomes a current location for the laser beam; adjust a number of scan parameters during a movement of the electromagnetic beam to scan the search area; and continue to move the electromagnetic beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the object has received the electromagnetic beam.

14. The electromagnetic beam transmission system of claim 13, wherein the number of scan parameters is selected from at least one of an overlap, a beam divergence, or a dwell time.

15. The electromagnetic beam transmission system of claim 13, wherein the object is selected from a group comprising an uncooperative object, a platform, a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and an electromagnetic beam receiver.

16. A method for pointing a laser beam, the method comprising:

directing the laser beam at a central location in a search area in which a satellite is expected to be located; moving the laser beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location, wherein the next location becomes a current location for the laser beam;

adjusting a number of scan parameters during a movement of the laser beam to scan the search area; and continuing to move the laser beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the object has received the laser beam.

17. The method of claim 16, wherein adjusting the number of scan parameters comprises:

decreasing an overlap during the movement of the laser beam to scan the search area.

18. The method of claim 17, wherein decreasing the overlap comprises:

decreasing the overlap at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the overlap at locations in a layer is uniform.

19. The method of claim 16, wherein in adjusting the number of scan parameters comprises:

increasing a beam divergence of the laser beam during the movement of the laser beam to scan the search area.

20. The method of claim 19, wherein increasing the beam divergence comprises:

increasing the beam divergence of the laser beam at each layer during the movement of the laser beam to scan the search area, wherein the beam divergence of the laser beam at locations in a layer is uniform.

21. The method of claim 16, wherein adjusting the number of scan parameters, the controller is configured to:

decrease a dwell time for the laser beam during the movement of the laser beam to scan the search area.

22. The method of claim 16, wherein decreasing the dwell time comprises:

decreasing the dwell time for the laser beam at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the dwell time of the laser beam at locations in a layer is uniform.

23. An electromagnetic beam receiver system comprising: an electromagnetic signal receiver configured to receive electromagnetic signals; and

a controller configured to control the electromagnetic signal receiver to:

move a field of view of the electromagnetic signal receiver to a central location in a search area in which an electromagnetic signal source is expected to be located;

move the field of view to a next location that is a nearest neighbor to the central location in response to not detecting the electromagnetic signals from the electromagnetic signal source at the central location, wherein the next location becomes a current location for the field of view;

adjust a number of scan parameters during a movement of the field of view to scan the search area; and continue to move the field of view from the current location to the next location that is the nearest neighbor to the current location in response to not detecting electromagnetic signals from the electromagnetic signal source.

* * * * *