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(54) **LASER SCANNING FOR SPATIAL ACQUISITION OF A SATELLITE RECEIVER**

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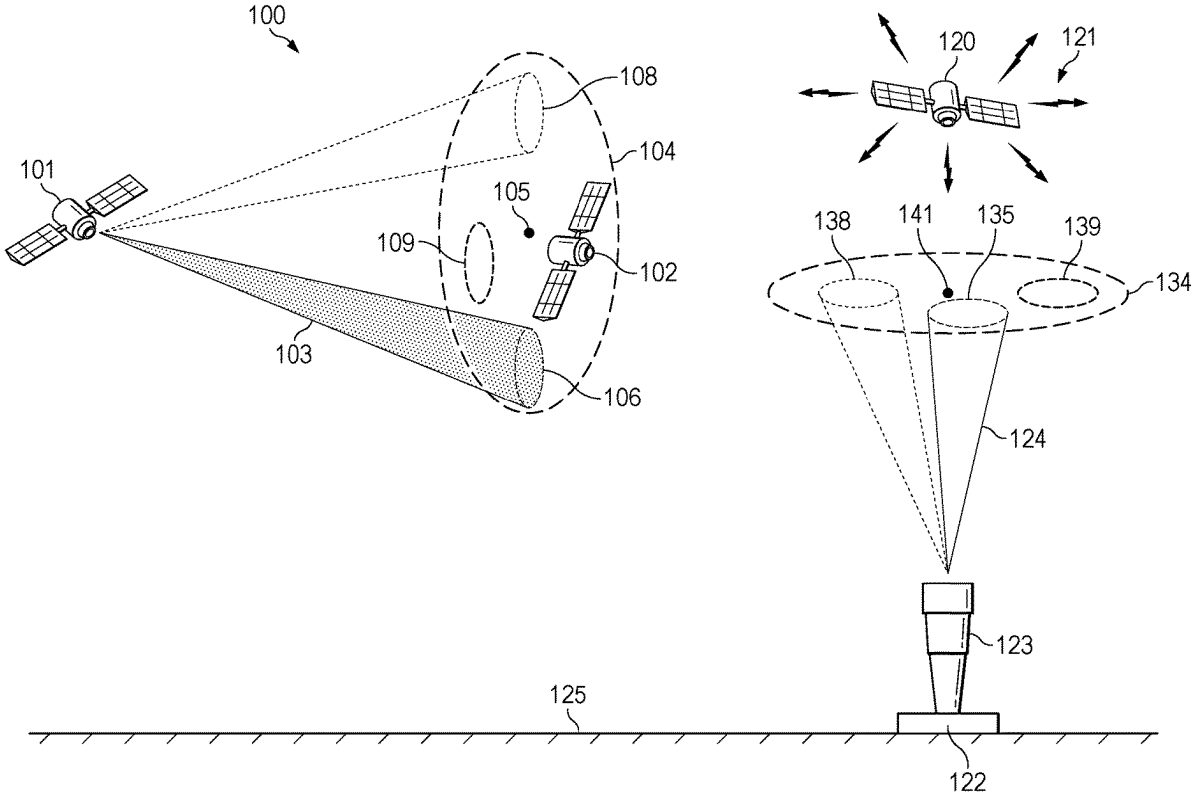
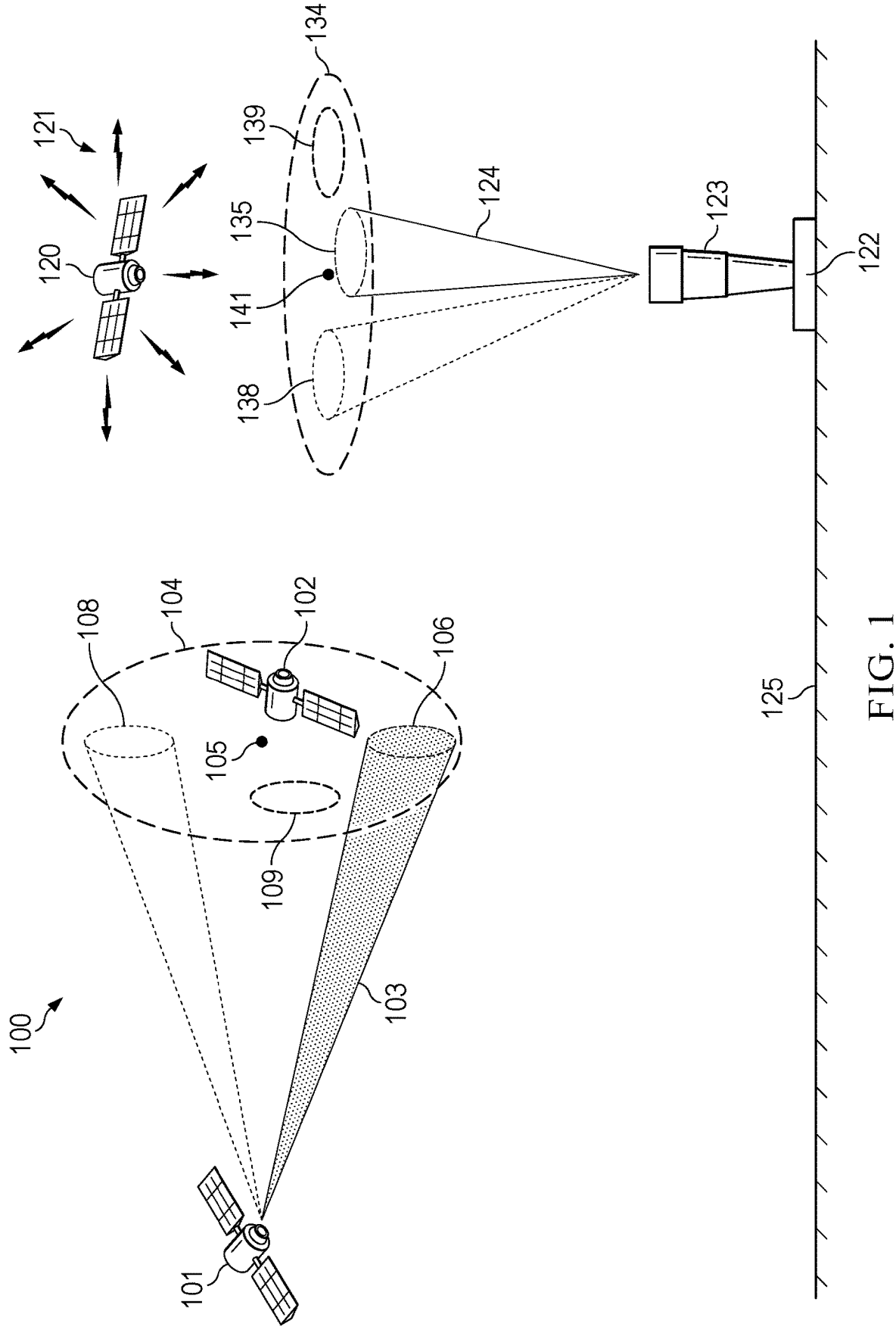
(57) **ABSTRACT**

A laser beam transmission system comprises a laser beam system and a controller that controls the laser beam system. The controller is configured to direct a laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located. The controller is configured 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. The next location becomes a current location for the laser beam. The controller is configured 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.




134
139
121
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108
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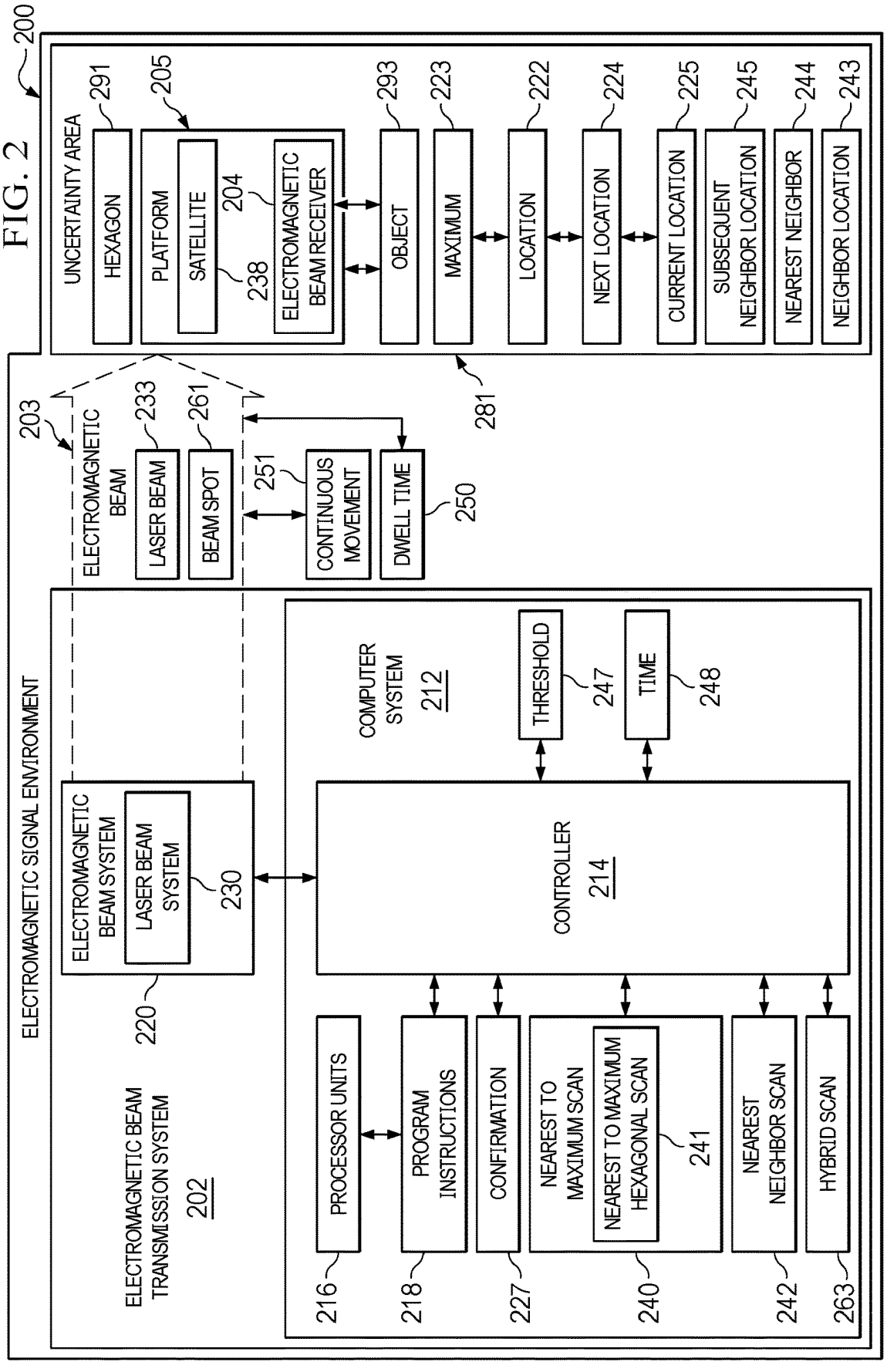
103
100
101

FIG. 1

FIG. 2


200
UNCERTAINTY AREA
HEXAGON
291
PLATFORM
205
SATELLITE
204
238
ELECTROMAGNETIC BEAM RECEIVER
OBJECT
293
MAXIMUM
223
LOCATION
222
NEXT LOCATION
224
CURRENT LOCATION
225
SUBSEQUENT NEIGHBOR LOCATION
245
NEAREST NEIGHBOR
244
NEIGHBOR LOCATION
243
281
203
ELECTROMAGNETIC BEAM
LASER BEAM
233
BEAM SPOT
261
251
CONTINUOUS MOVEMENT
DWELL TIME
250
ELECTROMAGNETIC SIGNAL ENVIRONMENT
ELECTROMAGNETIC BEAM SYSTEM
LASER BEAM SYSTEM
230
220
ELECTROMAGNETIC BEAM TRANSMISSION SYSTEM
202
COMPUTER SYSTEM
212
THRESHOLD
247
TIME
248
CONTROLLER
214
PROCESSOR UNITS
216
PROGRAM INSTRUCTIONS
218
CONFIRMATION
227
NEAREST TO MAXIMUM SCAN
NEAREST TO MAXIMUM HEXAGONAL SCAN
241
240
NEAREST NEIGHBOR SCAN
242
HYBRID SCAN
263

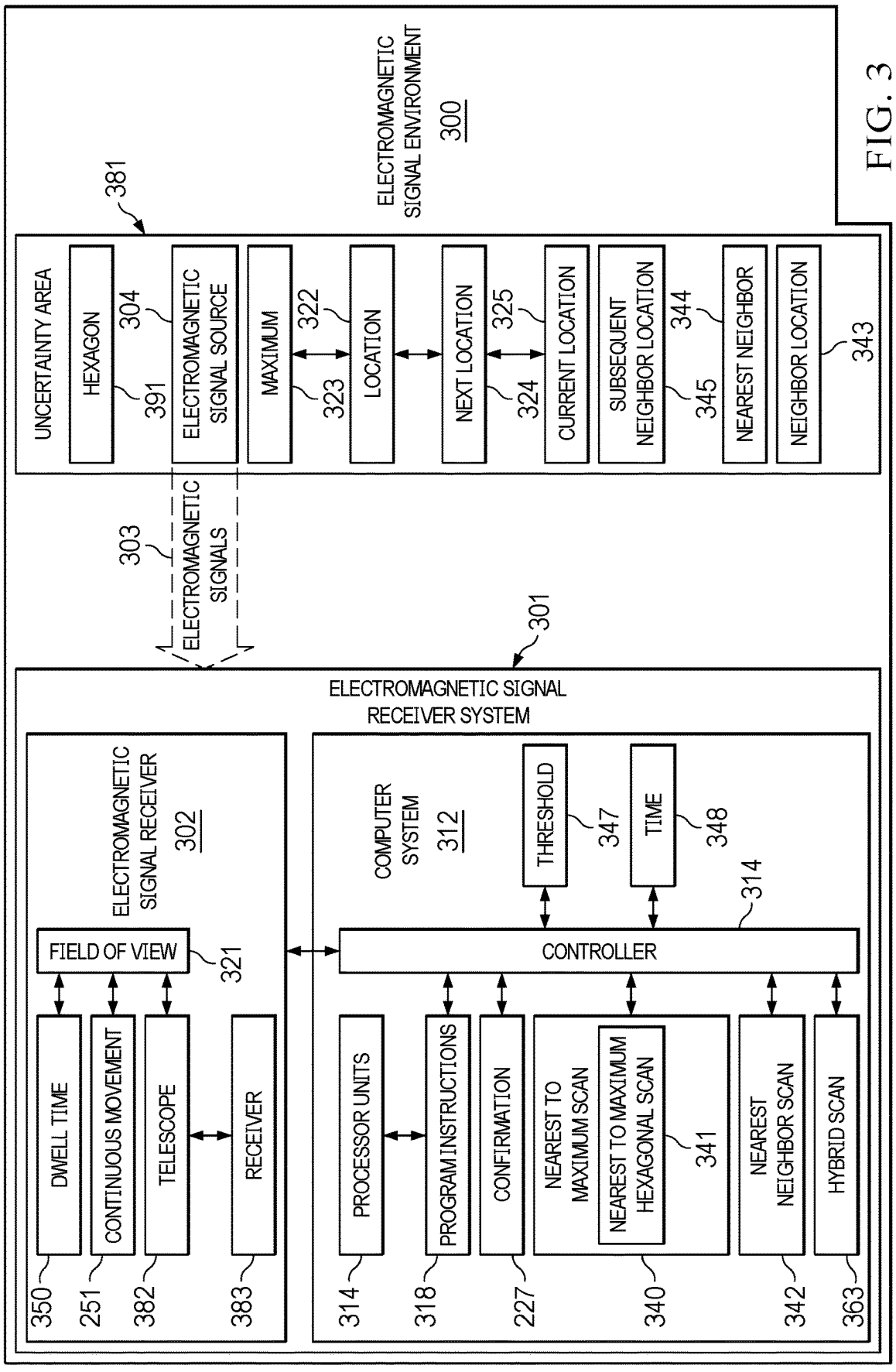

ELECTROMAGNETIC SIGNAL ENVIRONMENT
300
381
UNCERTAINTY AREA
HEXAGON
391
304
ELECTROMAGNETIC SIGNAL SOURCE
MAXIMUM
323
322
LOCATION
NEXT LOCATION
324
325
CURRENT LOCATION
SUBSEQUENT NEIGHBOR LOCATION
345
344
NEAREST NEIGHBOR
NEIGHBOR LOCATION
343
303
ELECTROMAGNETIC SIGNALS
301
ELECTROMAGNETIC SIGNAL RECEIVER SYSTEM
ELECTROMAGNETIC SIGNAL RECEIVER
302
FIELD OF VIEW
321
DWELL TIME
CONTINUOUS MOVEMENT
TELESCOPE
RECEIVER
350
251
382
383
COMPUTER SYSTEM
312
THRESHOLD
347
TIME
348
314
CONTROLLER
PROCESSOR UNITS
PROGRAM INSTRUCTIONS
CONFIRMATION
NEAREST TO MAXIMUM SCAN
NEAREST TO MAXIMUM HEXAGONAL SCAN
341
NEAREST NEIGHBOR SCAN
HYBRID SCAN
314
318
227
340
342
363

FIG. 3

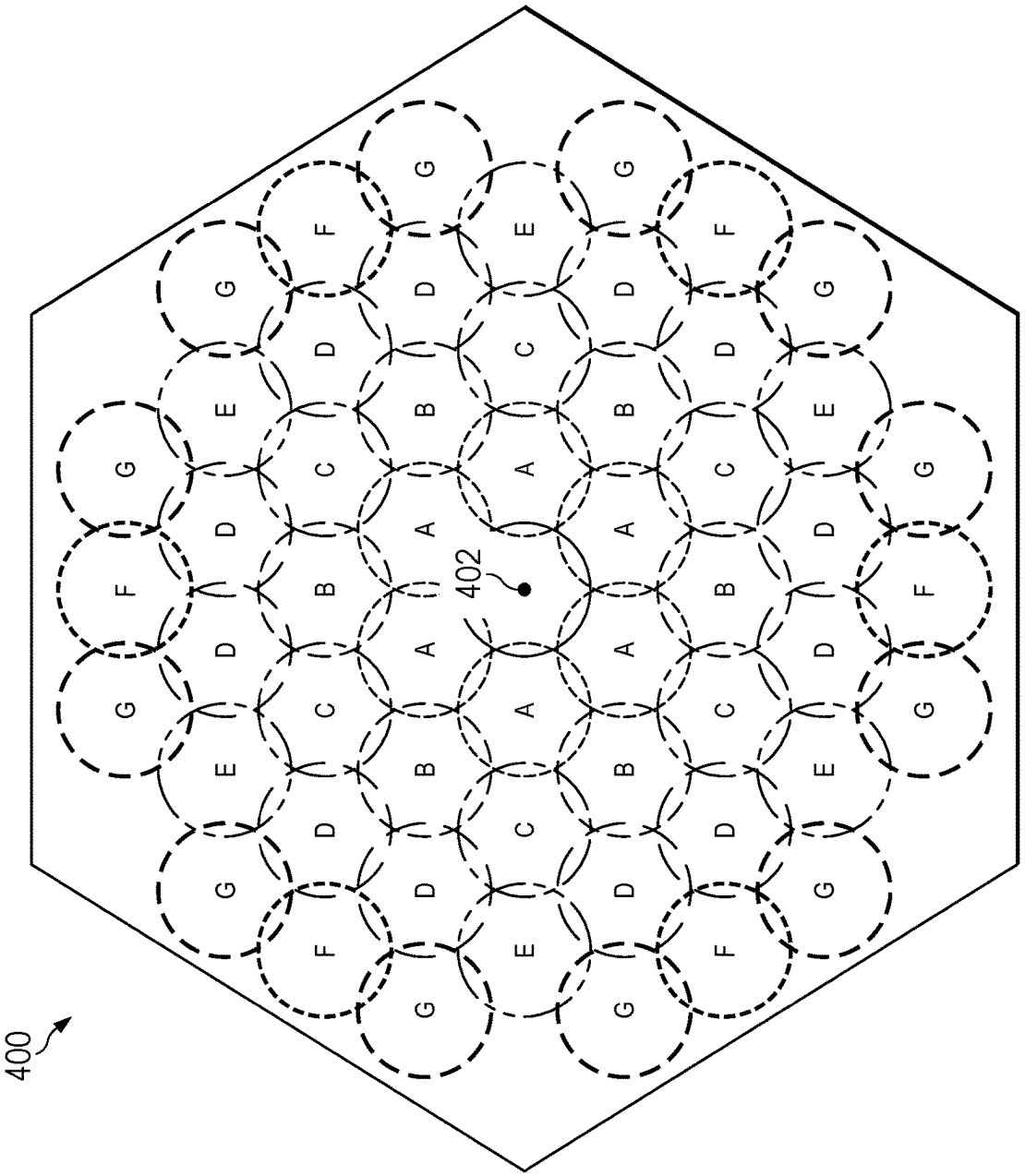


FIG. 4

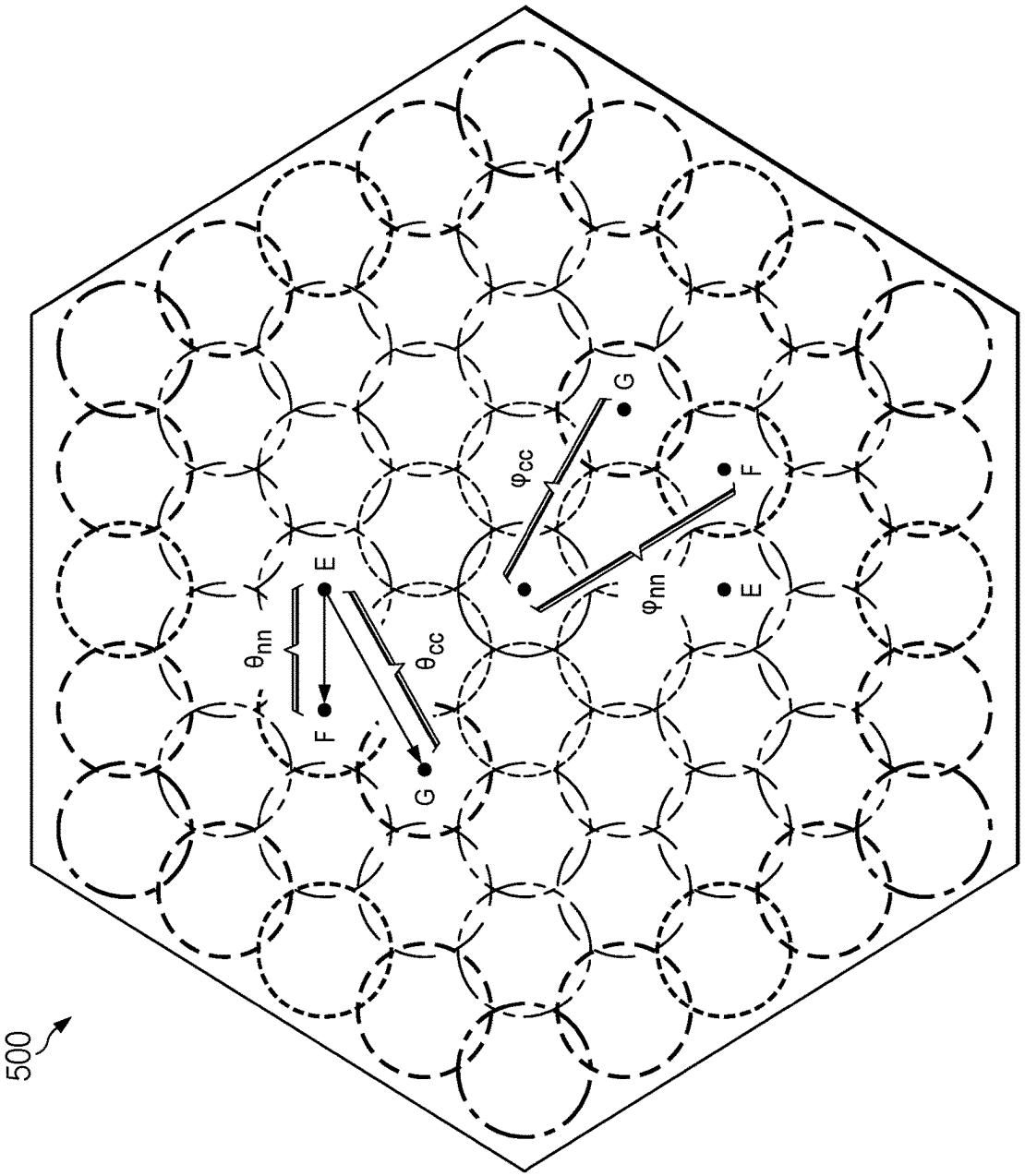


FIG. 5

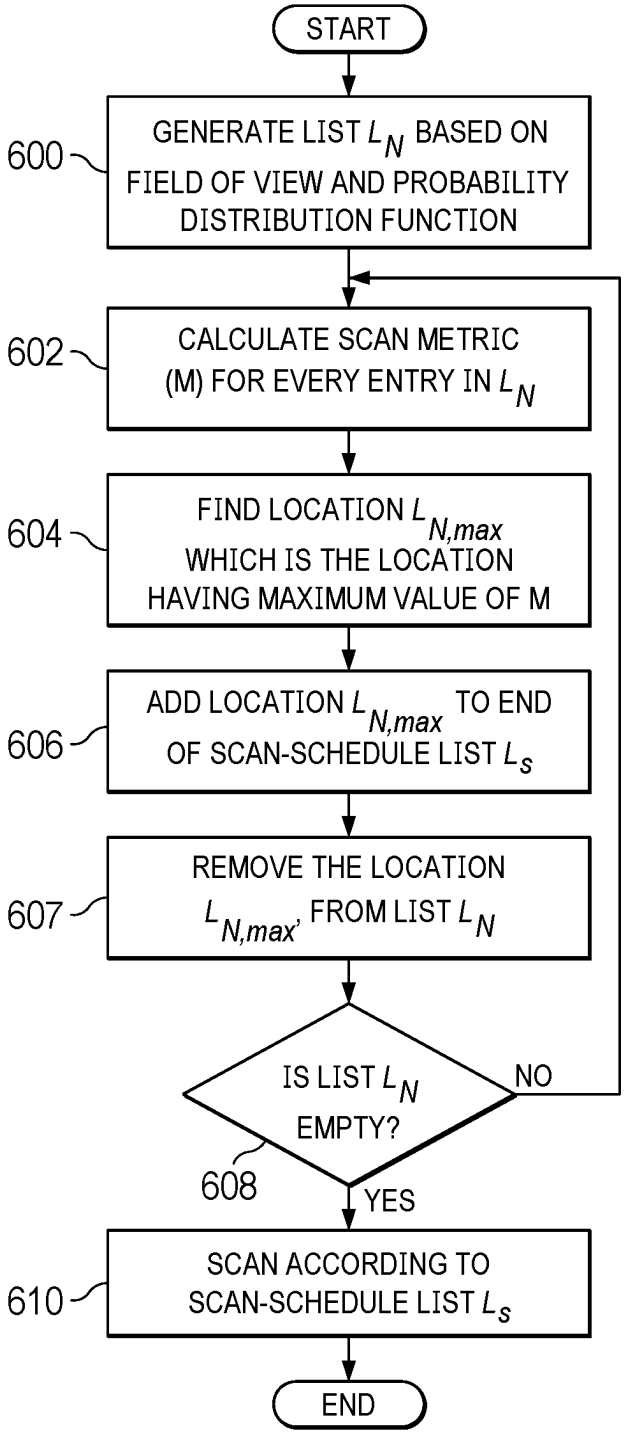

START
600
GENERATE LIST L_N BASED ON FIELD OF VIEW AND PROBABILITY DISTRIBUTION FUNCTION
602
CALCULATE SCAN METRIC (M) FOR EVERY ENTRY IN L_N
604
FIND LOCATION $L_{N,max}$ WHICH IS THE LOCATION HAVING MAXIMUM VALUE OF M
606
ADD LOCATION $L_{N,max}$ TO END OF SCAN-SCHEDULE LIST L_s
607
REMOVE THE LOCATION $L_{N,max}$, FROM LIST L_N
IS LIST L_N EMPTY?
608
NO
YES
610
SCAN ACCORDING TO SCAN-SCHEDULE LIST L_s
END

FIG. 6

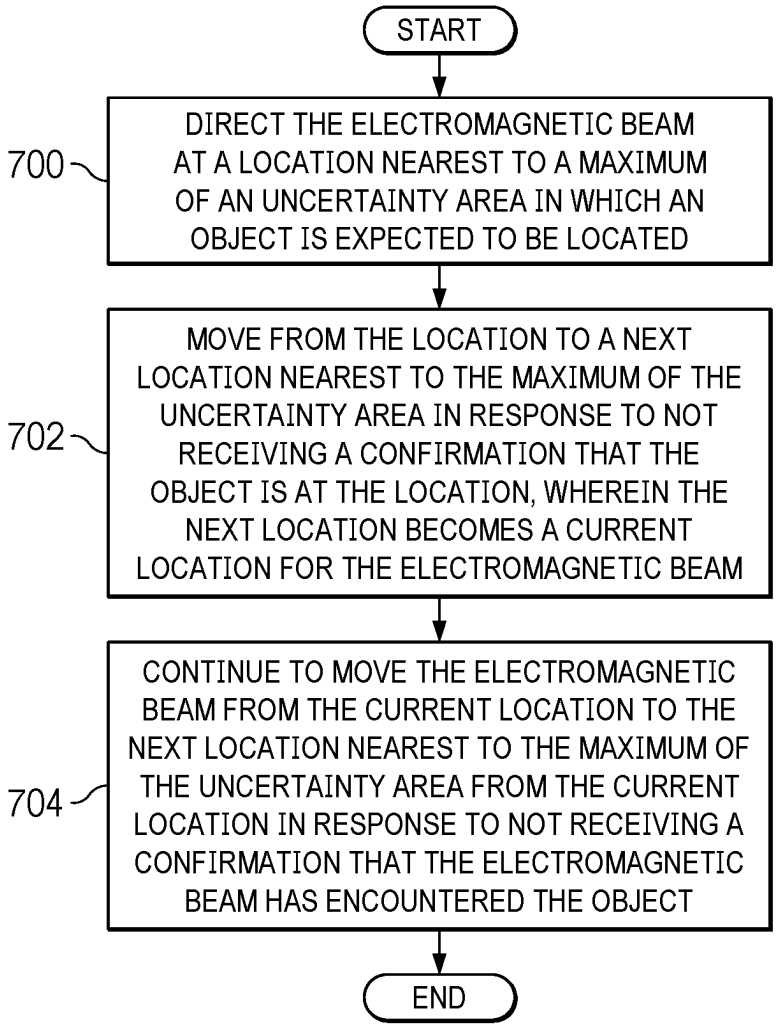

START
700
DIRECT THE ELECTROMAGNETIC BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH AN OBJECT IS EXPECTED TO BE LOCATED
702
MOVE FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE OBJECT IS AT THE LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE ELECTROMAGNETIC BEAM
704
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 A CONFIRMATION THAT THE ELECTROMAGNETIC BEAM HAS ENCOUNTERED THE OBJECT
END

FIG. 7

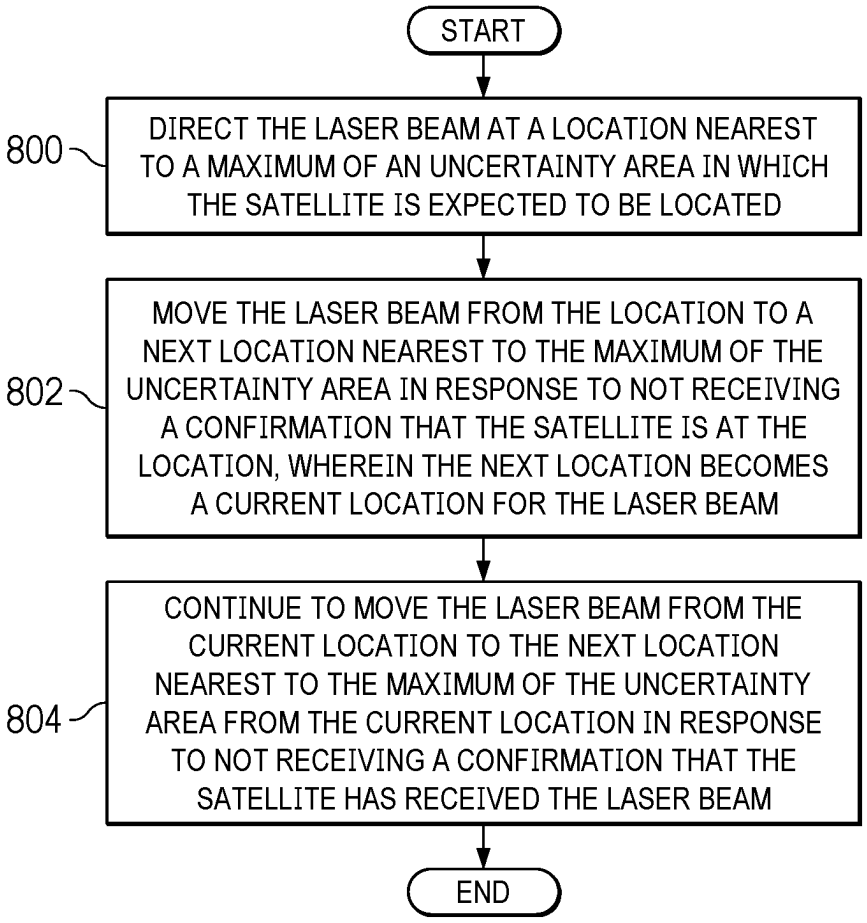

START
800
DIRECT THE LASER BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH THE SATELLITE IS EXPECTED TO BE LOCATED
802
MOVE THE LASER BEAM FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE IS AT THE LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE LASER BEAM
804
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 A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
END

FIG. 8

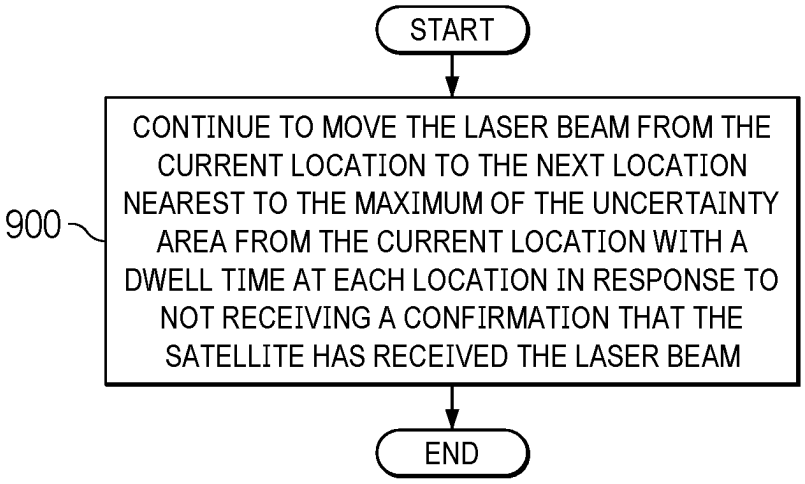

START
CONTINUE TO MOVE THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A DWELL TIME AT EACH LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
900
END

FIG. 9

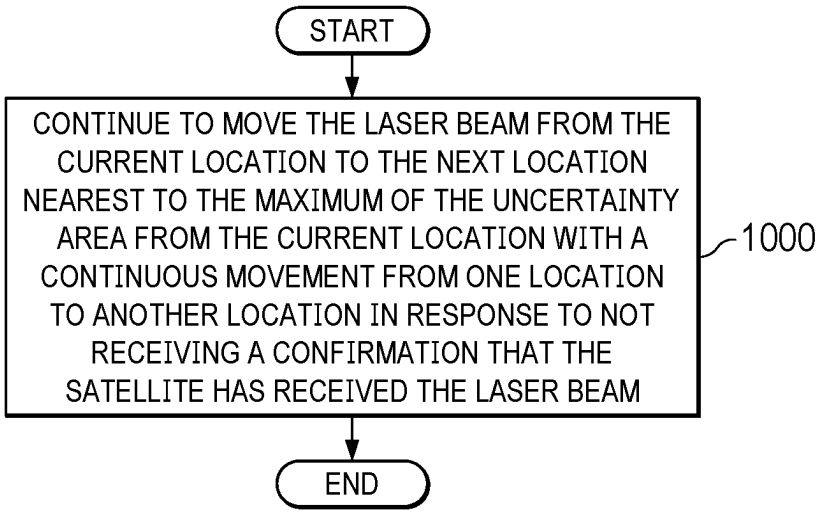

START
CONTINUE TO MOVE THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A CONTINUOUS MOVEMENT FROM ONE LOCATION TO ANOTHER LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
1000
END

FIG. 10

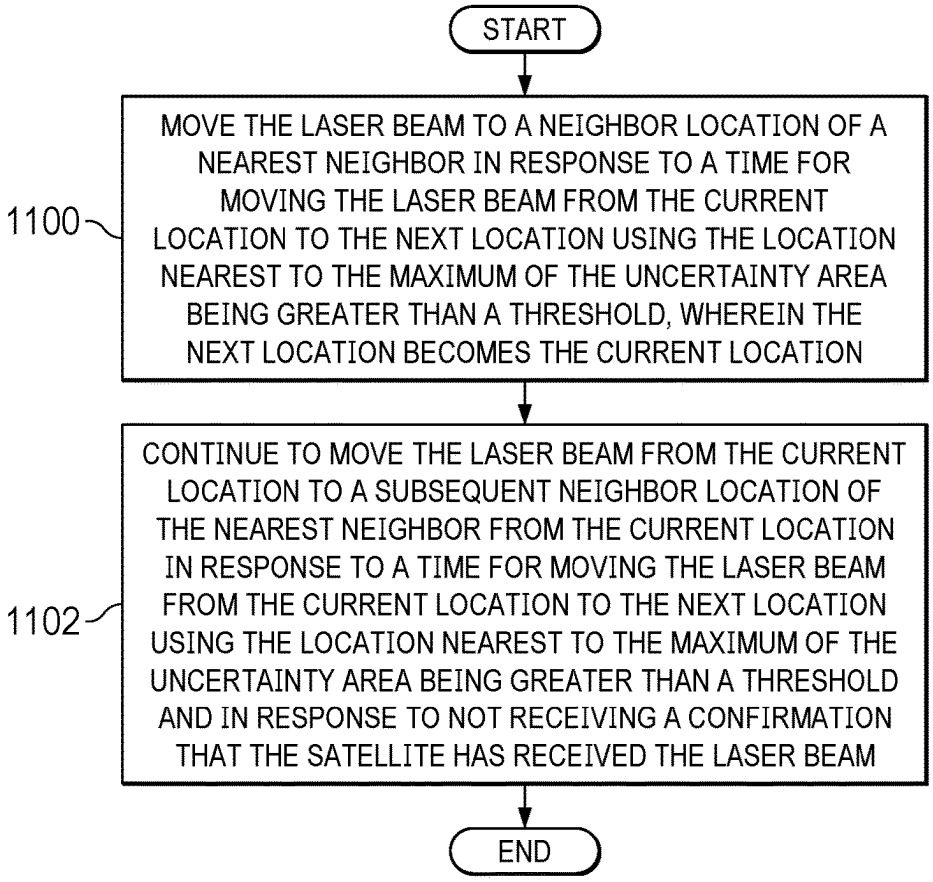

START
MOVE THE LASER BEAM TO A NEIGHBOR LOCATION OF A NEAREST NEIGHBOR IN RESPONSE TO A TIME FOR MOVING THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION USING THE LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA BEING GREATER THAN A THRESHOLD, WHEREIN THE NEXT LOCATION BECOMES THE CURRENT LOCATION
1100
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 A THRESHOLD AND IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
1102
END

FIG. 11

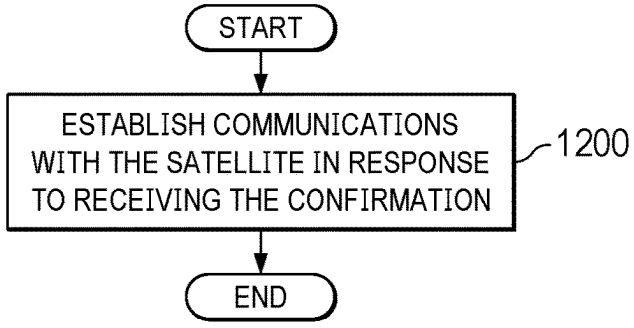

START
ESTABLISH COMMUNICATIONS WITH THE SATELLITE IN RESPONSE TO RECEIVING THE CONFIRMATION
1200
END

FIG. 12

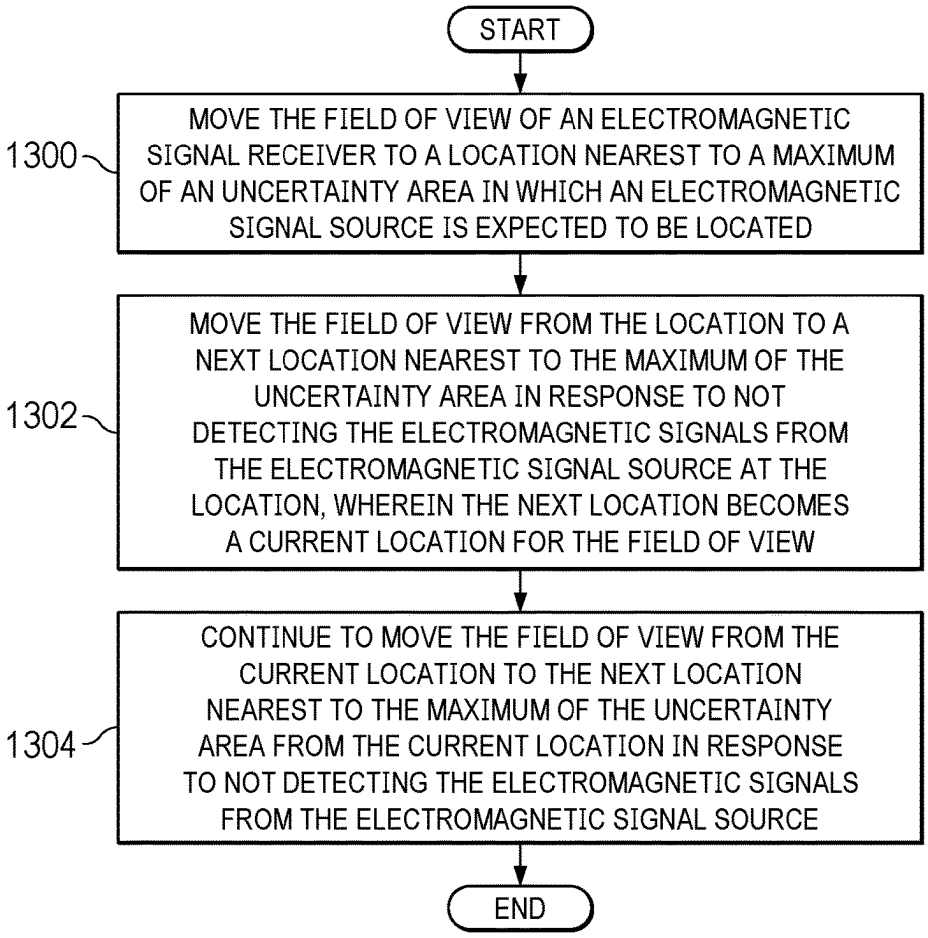

START
MOVE THE FIELD OF VIEW OF AN ELECTROMAGNETIC SIGNAL RECEIVER TO A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH AN ELECTROMAGNETIC SIGNAL SOURCE IS EXPECTED TO BE LOCATED
1300
MOVE THE FIELD OF VIEW FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA 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
1302
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
1304
END

FIG. 13

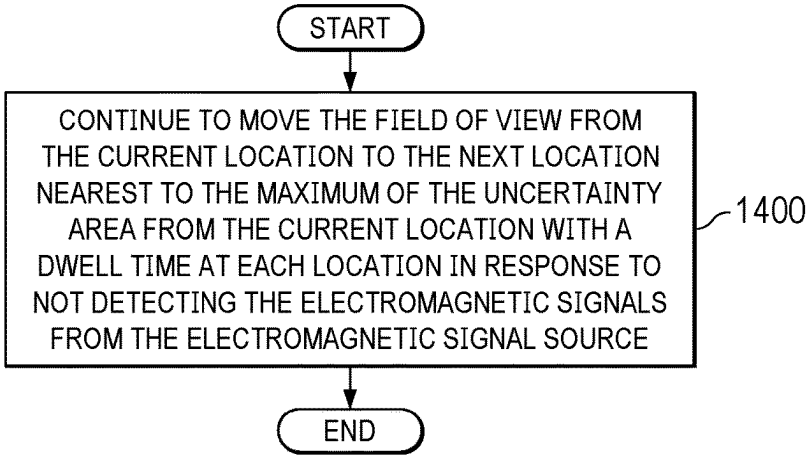

START
CONTINUE TO MOVE THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A DWELL TIME AT EACH LOCATION IN RESPONSE TO NOT DETECTING THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC SIGNAL SOURCE
1400
END

FIG. 14

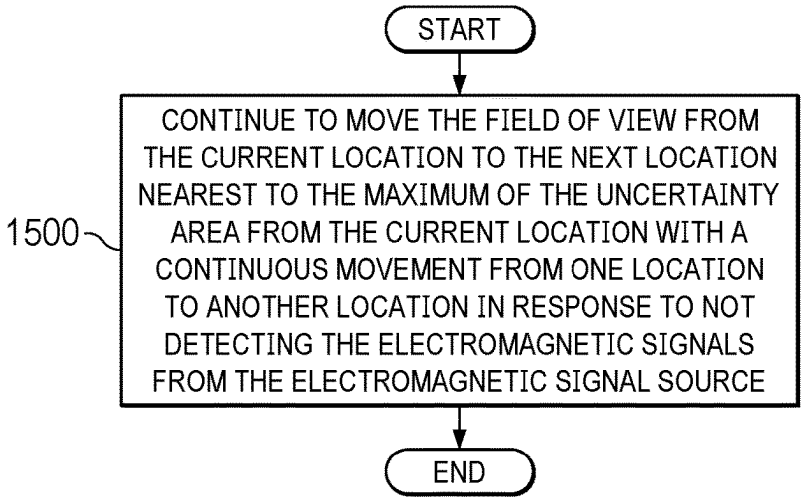

START
CONTINUE TO MOVE THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A CONTINUOUS MOVEMENT FROM ONE LOCATION TO ANOTHER LOCATION IN RESPONSE TO NOT DETECTING THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC SIGNAL SOURCE
1500
END

FIG. 15

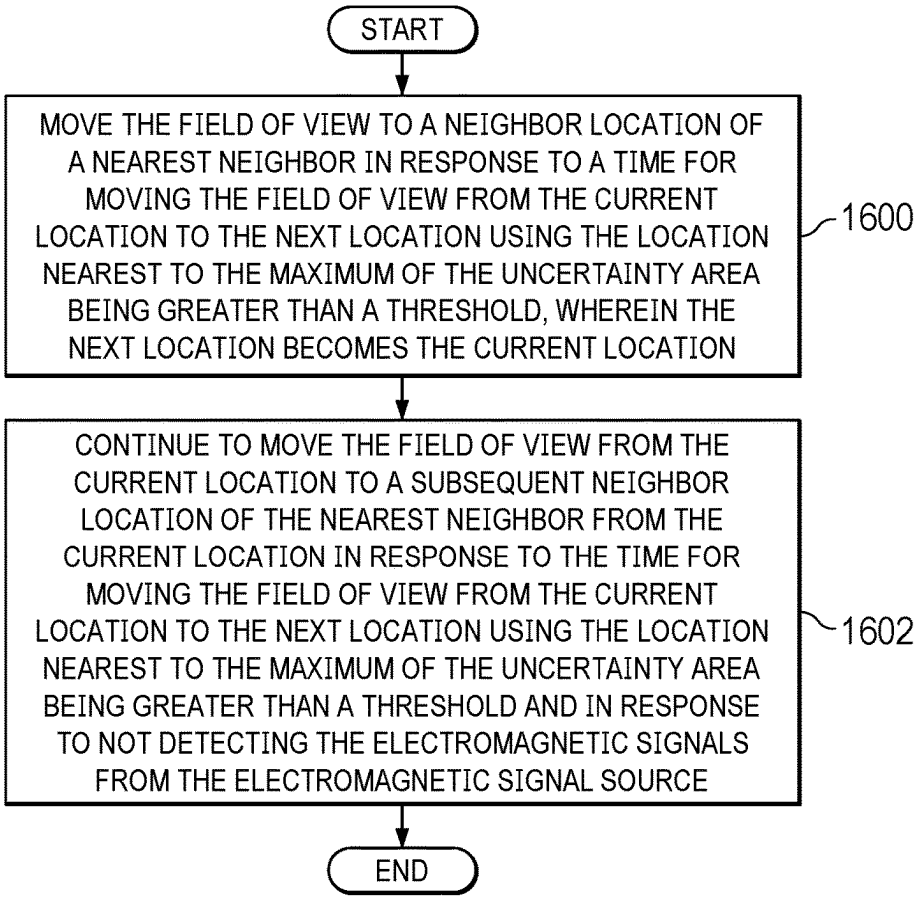

START
MOVE THE FIELD OF VIEW TO A NEIGHBOR LOCATION OF A NEAREST NEIGHBOR IN RESPONSE TO A TIME FOR MOVING THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION USING THE LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA BEING GREATER THAN A THRESHOLD, WHEREIN THE NEXT LOCATION BECOMES THE CURRENT LOCATION
1600
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 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
1602
END

FIG. 16

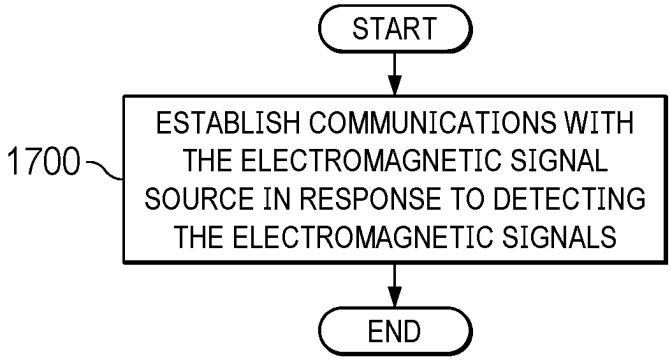

START
ESTABLISH COMMUNICATIONS WITH THE ELECTROMAGNETIC SIGNAL SOURCE IN RESPONSE TO DETECTING THE ELECTROMAGNETIC SIGNALS
1700
END

FIG. 17

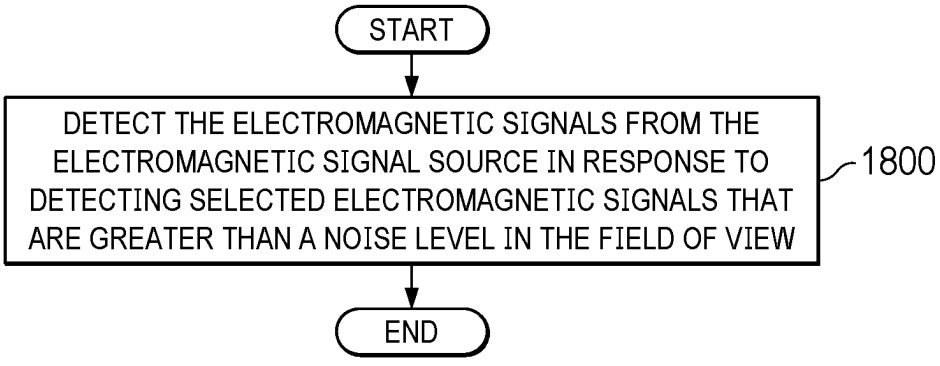

START
DETECT THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC SIGNAL SOURCE IN RESPONSE TO DETECTING SELECTED ELECTROMAGNETIC SIGNALS THAT ARE GREATER THAN A NOISE LEVEL IN THE FIELD OF VIEW
1800
END

FIG. 18

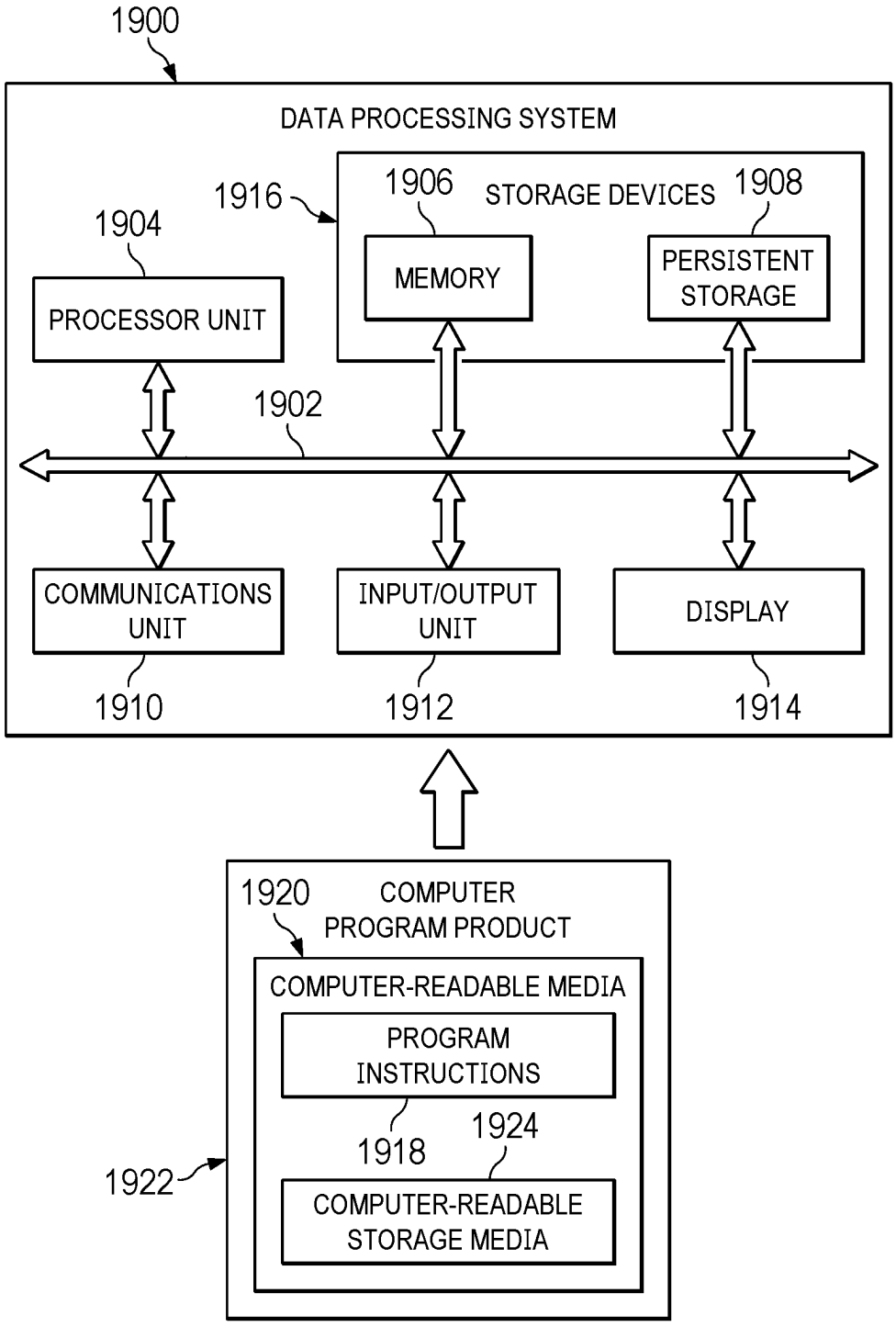

1900
DATA PROCESSING SYSTEM
1916
1906
STORAGE DEVICES
1908
1904
MEMORY
PERSISTENT STORAGE
PROCESSOR UNIT
1902
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
1910
1912
1914
1920
COMPUTER PROGRAM PRODUCT
COMPUTER-READABLE MEDIA
PROGRAM INSTRUCTIONS
1918
1924
1922
COMPUTER-READABLE STORAGE MEDIA

FIG. 19

LASER SCANNING FOR SPATIAL ACQUISITION OF A SATELLITE RECEIVER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is related to U.S. Patent Application entitled "Laser Sensor System With Pattern Scanning," Ser. No. _____, attorney docket no. 23-1025-US-NP[2], and U.S. Patent Application entitled "Laser Beam Based Flight Path Clearing System," Ser. No. _____, attorney docket no. 23-1025-US-NP[3], both of which are filed even date hereof, assigned to the same assignee, and incorporated herein by reference in their entirety.

BACKGROUND INFORMATION

1. Field

[0002] 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

[0003] 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.

[0004] 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

[0005] An example of the present disclosure provides a laser beam transmission system comprising a laser beam system configured to transmit a laser beam and a controller. The controller is configured to control the laser beam transmission system to direct the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located. The controller is 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. The next location becomes a current location for the laser beam. The controller is 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.

[0006] Another example of the present disclosure provides an electromagnetic beam transmission system comprising an electromagnetic beam system configured to transmit an electromagnetic beam and a controller. The controller is configured to control the electromagnetic beam transmission system to direct the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located. The controller is configured to control the electromagnetic beam transmission system to 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. The next location becomes a current location for the electromagnetic beam. The controller is configured to control the electromagnetic beam transmission system to 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.

[0007] Yet another example of the present disclosure provides an electromagnetic beam transmission system comprising an electromagnetic beam system configured to transmit an electromagnetic beam and a controller. The controller is configured to control the electromagnetic beam transmission system to direct the electromagnetic beam to a location in an uncertainty area using a scan metric. The uncertainty area is an area in which an object is expected to be located. The controller is configured to control the electromagnetic beam transmission system to 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. The next location becomes a current location for the electromagnetic beam. The controller is configured to control the electromagnetic beam transmission system to 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.

[0008] Still another example of the present disclosure provides a method for pointing a laser beam. The laser beam is directed at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located. The laser beam is moved 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. The next location becomes a current location for the laser beam. The laser beam continues 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 receiving the confirmation that the satellite has received the laser beam.

[0009] Still another example of the present disclosure provides a method for pointing an electromagnetic beam. The electromagnetic beam is directed at a location nearest to a maximum of an uncertainty area in which an object is expected to be located. The electromagnetic beam is moved 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. The next location becomes a current location for the electromagnetic beam. The electromagnetic beam continues to be 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features believed characteristic of the illustrative examples are set forth in the appended claims. The illustrative examples, 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 example of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0011] FIG. **1** is a pictorial illustration of a satellite communications environment in which illustrative examples may be implemented;

[0012] FIG. **2** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0013] FIG. **3** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0014] FIG. **4** is an illustration of locations for pointing an electromagnetic beam system or an electromagnetic signal receiver in accordance with an illustrative example;

[0015] FIG. **5** is an illustration of locations and beam spots and angles between beam spots in accordance with an illustrative example;

[0016] 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;

[0017] FIG. **7** is an illustration of a flowchart of a method for pointing an electromagnetic beam in accordance with an illustrative example;

[0018] FIG. **8** is an illustration of a flowchart of a method for pointing a laser beam in accordance with an illustrative example;

[0019] FIG. **9** is an illustration of a flowchart of a process for continuing to move a laser beam in accordance with an illustrative example;

[0020] FIG. **10** is an illustration of a flowchart of a process for continuing a laser beam in accordance with an illustrative example;

[0021] FIG. **11** is an illustration of a flowchart of a process for moving a laser beam in accordance with an illustrative example;

[0022] FIG. **12** is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0023] FIG. **13** is an illustration of a flowchart of a process for receiving electromagnetic signals in accordance with an illustrative example;

[0024] 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;

[0025] 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;

[0026] FIG. **16** is an illustration of a flowchart of an operation for moving a field of view in accordance with an illustrative example;

[0027] FIG. **17** is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0028] FIG. **18** is an illustration of a flowchart of a process for detecting electromagnetic signals in accordance with an illustrative example; and

[0029] FIG. **19** is an illustration of a block diagram of a data processing system in accordance with an illustrative example.

DETAILED DESCRIPTION

[0030] 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 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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**.

[0038] 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.

[0039] 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.

[0040] 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**.

[0041] 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.

[0042] 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.

[0043] 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 face 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**.

[0044] 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.

[0045] In this illustrative example, satellite **120** is expected to be within area **134**.

[0046] 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**.

[0047] 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**.

[0048] 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**.

[0049] 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.

[0050] 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.

[0051] 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.

[0052] 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.

[0053] 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**.

[0054] 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 telescope **123** can be located on a platform such as a vehicle, a ship, an aircraft, a building, or some other suitable location.

[0055] 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**.

[0056] 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.

[0057] 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**.

[0058] Electromagnetic beam system **220** is a physical hardware system. This hardware system is configured to transmit electromagnetic beam **203**.

[0059] 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**.

[0060] 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.

[0061] 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.

[0062] 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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**.

[0067] 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.

[0068] 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**.

[0069] 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.

[0070] 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**.

[0071] 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.

[0072] 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.

[0073] 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.

[0074] 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. 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.

[0075] 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.

[0076] 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.

[0077] 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.

[0078] 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 electromagnetic beam receiver **204** is at location **222**. In this example, next location **224** becomes current location **225** for electromagnetic beam **203**.

[0079] 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**.

[0080] 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.

[0081] 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**.

[0082] 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 **234** 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.

[0083] In continuing to continue 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**.

[0084] 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**.

[0085] 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**.

[0086] 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**.

[0087] 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.

[0088] 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.

[0089] 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.

[0090] 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.

[0091] 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**.

[0092] 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**.

[0093] 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.

[0094] 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.

[0095] 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.

[0096] 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**.

[0097] 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**.

[0098] 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.

[0099] 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.

[0100] 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.

[0101] 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**.

[0102] 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.

[0103] 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**.

[0104] 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**.

[0105] 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:

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

[0106] 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.

[0107] 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**.

[0108] 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.

[0109] 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.

[0110] 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 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.

[0111] 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.

[0112] 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**.

[0113] 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**.

[0114] 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).

[0115] 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 oil 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.

[0116] 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.

[0117] 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.

[0118] 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**.

[0119] 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**.

[0120] 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**.

[0121] 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**.

[0122] 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.

[0123] 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.

[0124] 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**.

[0125] 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**.

[0126] 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**.

[0127] 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.

[0128] 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.

[0129] 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**.

[0130] 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.

[0131] 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.

[0132] 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.

[0133] 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**.

[0134] 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**.

[0135] 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:

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

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.

[0136] 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.

[0137] 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**.

[0138] For example, the first location can be locations for center **402**. The next locations closest to center **402** are locations A.

[0139] 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.

[0140] 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.

[0141] 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.

[0142] As depicted, angle θcc 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.

[0143] 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:

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

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.

[0144] t_{scan} is the total scan time to use the nearest neighbor scan.

[0145] N is the total number of beam spots in the scan pattern.

[0146] PDF(φ_{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".

[0147] PDF(φ_{nn}) is the unitless value of the probability density function for the beam spot that was moved to for the nearest neighbor scan.

[0148] 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.

[0149] θ_{nn} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest neighbor scan.

[0150] 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

[0151] 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:

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

[0152] Since PDF(φ_{cc})cc)≥PDF(φ_{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

[0153] In this example, the slew rate can be considered zero resulting in the following:

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

[0154] In this case, the nearest to maximum scan is not needed because the $t_{net\ savings} < 0$.

Example 3

[0155] 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.

[0156] 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.

[0157] 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**.

[0158] In this example, the pointing involves moving or directing electromagnetic beam **203** in FIG. **2** or field of view **321** in FIG. **3**.

[0159] 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).

[0160] The process begins by generating a list L_N 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 (L_N) (operation **602**).

[0161] 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.

[0162] 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.

[0163] 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.

[0164] 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.

[0165] 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**.

[0166] 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**).

[0167] 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.

[0168] 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.

[0169] 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**.

[0170] 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.

[0171] 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.

[0172] 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**.

[0173] 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.

[0174] 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**.

[0175] 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.

[0176] 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**.

[0177] 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.

[0178] 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.

[0179] 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**.

[0180] 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.

[0181] 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 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 **314** in computer system **312** in electromagnetic signal receiver system **301** in FIG. **3**.

[0182] 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**).

[0183] 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.

[0184] 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**.

[0185] 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.

[0186] 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**.

[0187] 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.

[0188] 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**.

[0189] 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.

[0190] 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.

[0191] 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**.

[0192] The process establishes communications with the electromagnetic signal source in response to detecting the electromagnetic signals (operation **1700**). The process terminates thereafter.

[0193] 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**.

[0194] 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 communica-

tions are selected from one of unidirectional communications and bidirectional communications.

[0195] The flowcharts and block diagrams in the different depicted examples 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.

[0196] 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.

[0197] 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**.

[0198] 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.

[0199] 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.

[0200] 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.

[0201] 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**.

[0202] 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.

[0203] 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.

[0204] 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**.

[0205] 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**.

[0206] 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**.

[0207] 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 (RAN), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access

memory (SPA), 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.

[0208] 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.

[0209] 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.

[0210] 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.

[0211] 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.

[0212] 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**.

[0213] 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

[0214] A laser beam transmission system comprising:

[0215] a laser beam system configured to transmit a laser beam;

[0216] a controller configured to control the laser beam system to:

[0217] direct the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

[0218] 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

[0219] 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

[0220] 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

[0221] The laser beam transmission system of clause 1, wherein in continuing to move the laser beam, the controller is configured to:

[0222] 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

[0223] The laser beam transmission system of clause 1, wherein in continuing to move the laser beam, the controller is configured to:

[0224] 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

[0225] The laser beam transmission system of clause 1, wherein the controller is configured to control the laser beam system to:

[0226] 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

[0227] 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

[0228] 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

[0229] The laser beam transmission system of clause 1, wherein the controller is configured to:

[0230] establish communications with the satellite in response to receiving the confirmation.

Clause 8

[0231] The laser beam transmission system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0232] 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

[0233] An electromagnetic beam transmission system comprising:

[0234] an electromagnetic beam system configured to transmit an electromagnetic beam;

[0235] a controller configured to control the electromagnetic beam transmission system to:

[0236] direct the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0237] 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

[0238] 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

[0239] 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.

[0240] Clause 12. An electromagnetic beam transmission system comprising:

[0241] an electromagnetic beam system configured to transmit an electromagnetic beam;

[0242] a controller configured to control the electromagnetic beam transmission system to:

[0243] 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;

[0244] 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

[0245] 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

[0246] 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:

$$M = PDFint/ttot$$

[0247] 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 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

[0248] A method for pointing a laser beam, the method comprising:

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

[0250] 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

[0251] 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

[0252] 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

[0253] The method of clause 14, wherein continuing to move the laser beam comprises:

[0254] 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

[0255] The method of clause 14, wherein continuing to move the laser beam comprises:

[0256] 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

[0257] The method of clause 14 further comprising:

[0258] 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

[0259] 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

[0260] 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

[0261] The method of clause 14 further comprising:

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

Clause 21

[0263] The method of clause 20, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0264] 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

[0265] A method for pointing an electromagnetic beam, the method comprising:

[0266] directing the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0267] 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

[0268] 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.

[0269] 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.

[0270] 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.

[0271] 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.

[0272] 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

[0273] An electromagnetic signal receiver system comprising:

[0274] an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;

[0275] a controller configured to control the electromagnetic signal receiver to:

[0276] 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;

[0277] 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

[0278] 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

[0279] 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.

[0280] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0281] 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

[0282] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0283] 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

[0284] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to control the electromagnetic signal receiver system to:

[0285] 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

[0286] 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

[0287] 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

[0288] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:

[0289] establish communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 8

[0290] The electromagnetic signal receiver system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0291] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:

[0292] 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

[0293] The electromagnetic signal receiver system of clause 1, wherein the electromagnetic signal receiver is selected from a group comprising a telescope.

Clause 11

[0294] 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

[0295] An electromagnetic signal receiver system comprising:

[0296] an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;

[0297] a controller configured to control the electromagnetic signal receiver to:

[0298] 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;

[0299] 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

[0300] 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

[0301] 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:

$$M = PDFint/ttot$$

[0302] 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 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

[0303] A method for receiving electromagnetic signals comprising:

[0304] 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;

[0305] 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

[0306] 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

[0307] 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

[0308] The method of clause 14, wherein continuing to move the field of view comprises:

[0309] 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.

[0310] 17. The method of claim **14**, continuing to move the field of view comprises:

[0311] 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

[0312] The method of clause 14 further comprising:

[0313] 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

[0314] 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

[0315] 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

[0316] The method of clause 14 further comprising:

[0317] establishing communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 21

[0318] The method of clause 20 wherein the communications is selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0319] The method of clause 14 further comprising:

[0320] 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

[0321] 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.

[0322] The description of the different illustrative examples has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the examples in the form disclosed. The different illustrative examples describe components that perform actions or operations. In an illustrative example, 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.

[0323] Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative examples may provide different features as compared to other desirable examples. The example or examples selected are chosen and described in order to best explain the principles of the examples, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various examples 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 location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

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

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.

2. The laser beam transmission system of claim **1**, wherein a movement of the laser beam is in a form of a nearest to maximum hexagonal scan.

3. The laser beam transmission system of claim **1**, wherein in continuing to move the laser beam, the controller is configured 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 with a dwell time at each location in response to not receiving the confirmation that the satellite has received the laser beam.

4. The laser beam transmission system of claim **1**, wherein in continuing to move the laser beam, the controller is configured 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 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.

5. The laser beam transmission system of claim **1**, wherein 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, wherein the next location becomes the current location; and

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.

6. The laser beam transmission system of claim **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.

7. 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.

8. The laser beam transmission system of claim **7**, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

9. 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.

10. 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 transmission system to:

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

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

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.

11. The electromagnetic beam transmission system of claim **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.

12. 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 transmission system to:

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;

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

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.

13. The electromagnetic beam transmission system of claim **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:

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

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 the current location to the next potential location, and t_{dwell} is a time the line of site dwells at the next potential location.

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

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

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

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.

15. The method of claim **14**, wherein a movement of the laser beam is in a form of a nearest to maximum hexagonal scan.

16. The method of claim **14**, wherein continuing to move the laser beam comprises:

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.

17. The method of claim **14**, wherein continuing to move the laser beam comprises:

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.

18. The method of claim **14** further comprising:

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

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.

19. The method of claim **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.

20. The method of claim **14** further comprising:

establishing communications with the satellite in response to receiving the confirmation.

21. The method of claim **20**, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

22. The method of claim **14**, wherein the laser beam is selected is selected from a group comprising a continuous laser beam and a pulsed laser beam.

23. A method for pointing an electromagnetic beam, the method comprising:

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

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

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.

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