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Hiller

(54) **NONLINEAR LASER BEAM SCAN PATTERN**

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G01S 17/06	(2006.01)
H04B 10/118	(2013.01)

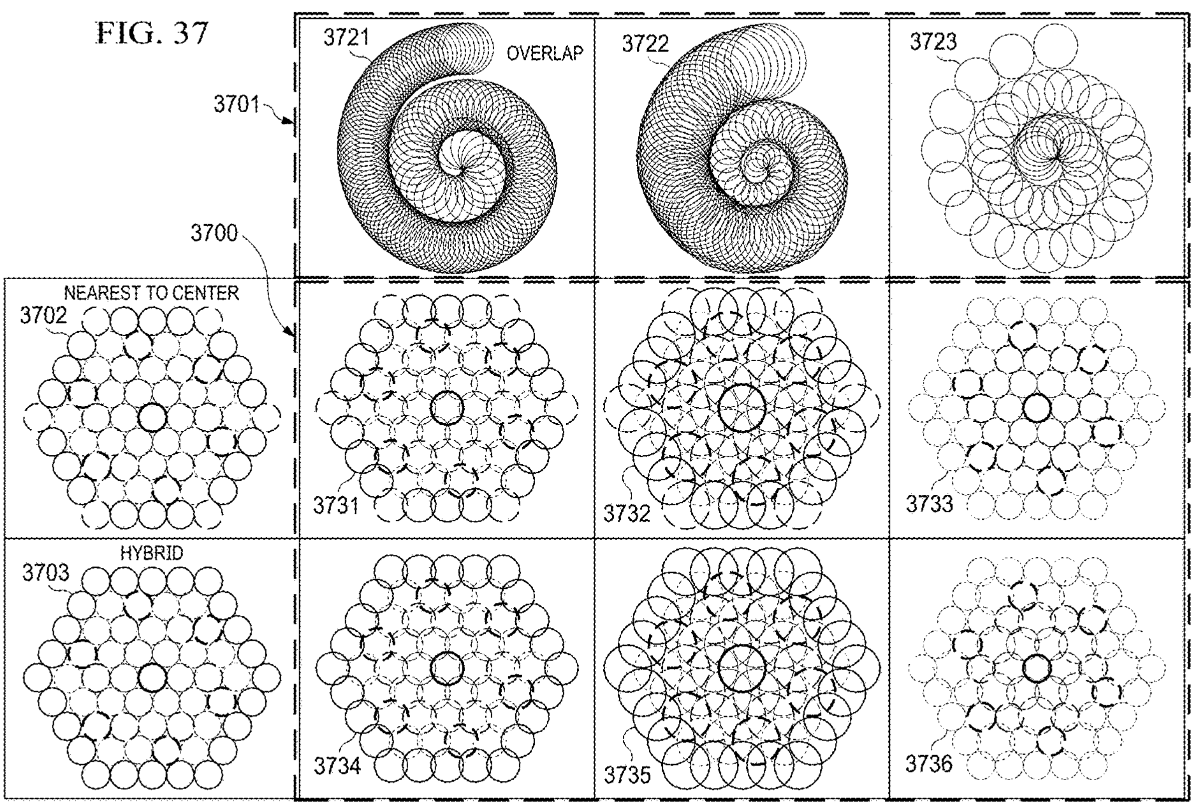
(52) **U.S. Cl.**

CPC ***G01S 7/4972*** (2013.01); ***G01S 17/06*** (2013.01); ***H04B 10/118*** (2013.01)

(57) **ABSTRACT**

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 number of scan parameters is adjusted during a movement of the laser beam to scan the uncertainty area. The laser beam 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 receiving the confirmation that the satellite has received the laser beam.

FIG. 37



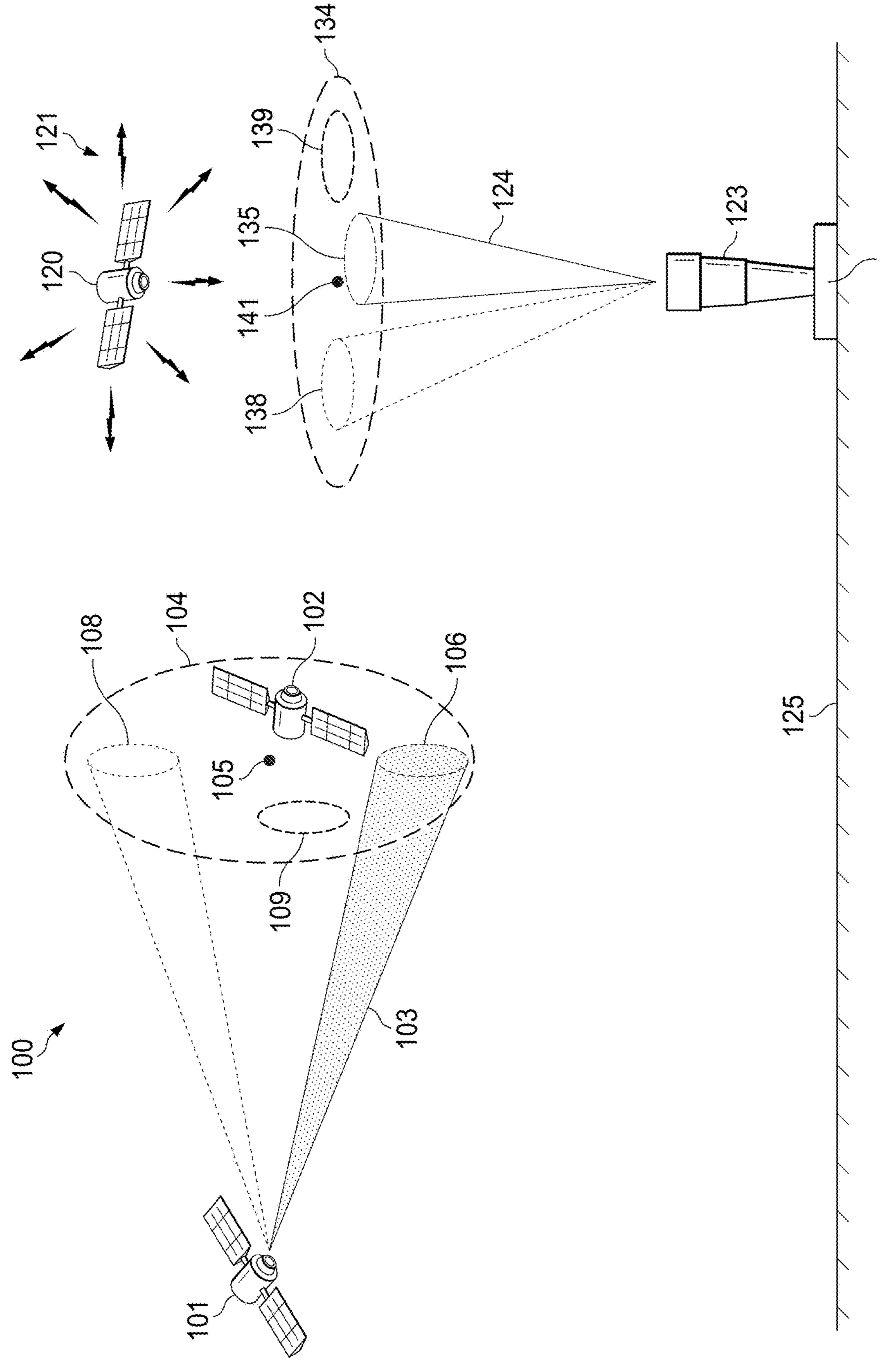
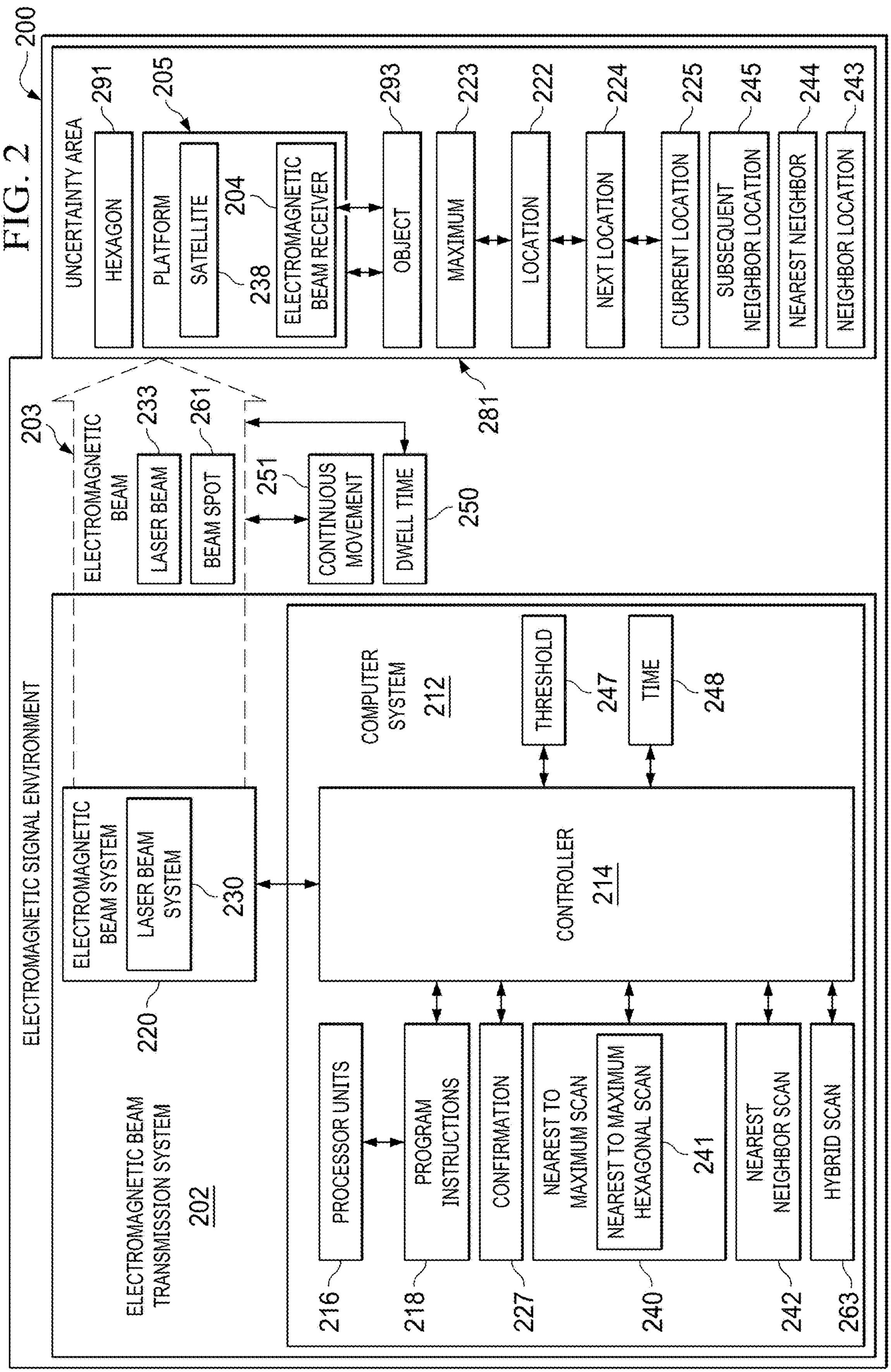
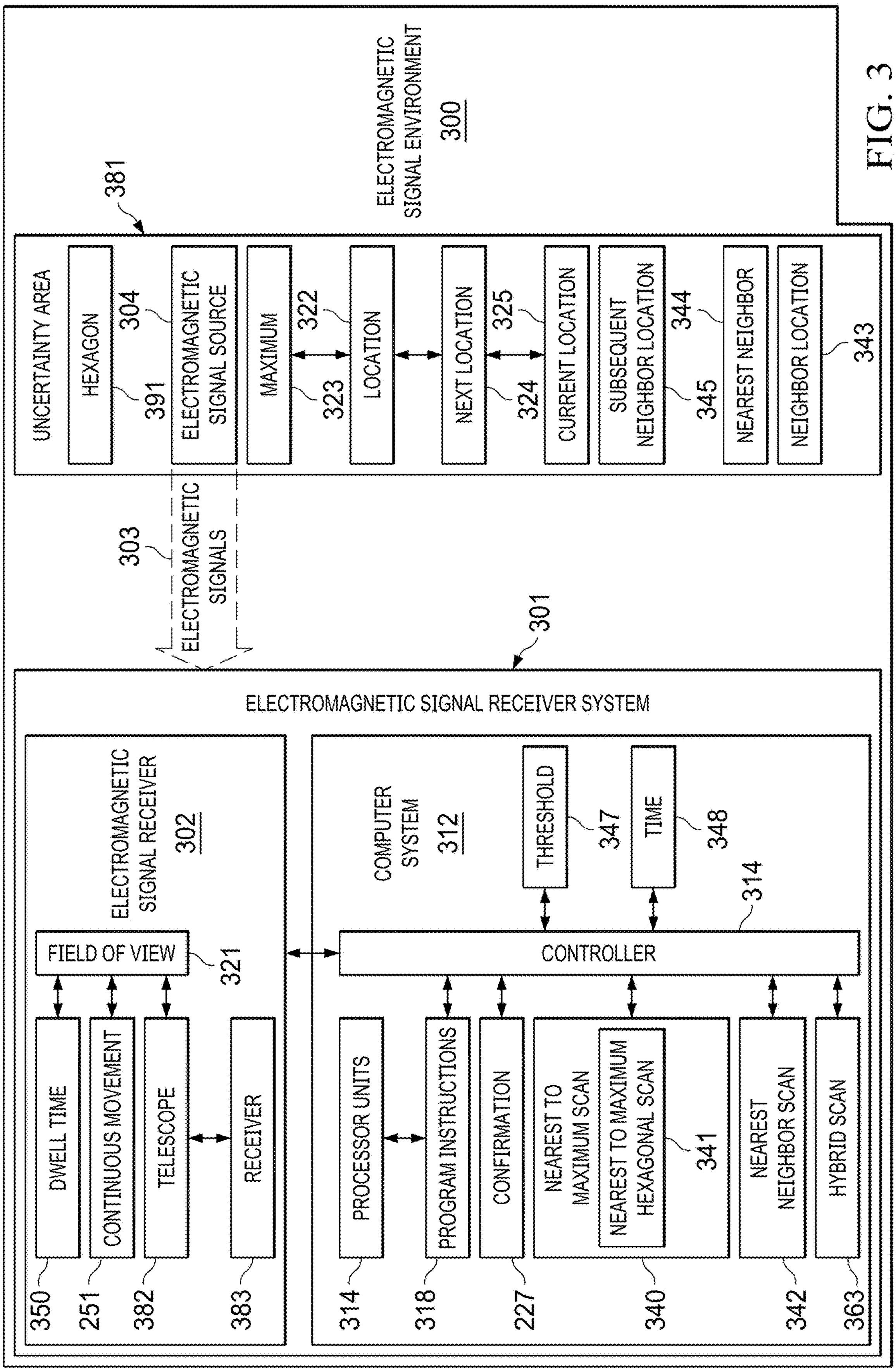

100
101
102
103
104
105
106
108
109
120
121
122
123
124
125
134
135
138
139
141

FIG. 1

FIG. 2


200
ELECTROMAGNETIC SIGNAL ENVIRONMENT
UNCERTAINTY AREA
HEXAGON
291
PLATFORM
205
SATELLITE
238
ELECTROMAGNETIC BEAM RECEIVER
204
OBJECT
293
MAXIMUM
223
LOCATION
222
NEXT LOCATION
224
CURRENT LOCATION
225
SUBSEQUENT NEIGHBOR LOCATION
245
NEAREST NEIGHBOR
244
NEIGHBOR LOCATION
243
281
ELECTROMAGNETIC BEAM
203
LASER BEAM
233
BEAM SPOT
261
CONTINUOUS MOVEMENT
251
DWELL TIME
250
ELECTROMAGNETIC BEAM TRANSMISSION SYSTEM
202
ELECTROMAGNETIC BEAM SYSTEM
LASER BEAM SYSTEM
230
220
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
350
CONTINUOUS MOVEMENT
251
TELESCOPE
382
RECEIVER
383
COMPUTER SYSTEM
312
THRESHOLD
347
TIME
348
314
CONTROLLER
PROCESSOR UNITS
314
PROGRAM INSTRUCTIONS
318
CONFIRMATION
227
NEAREST TO MAXIMUM SCAN
NEAREST TO MAXIMUM HEXAGONAL SCAN
341
340
NEAREST NEIGHBOR SCAN
342
HYBRID SCAN
363

FIG. 3

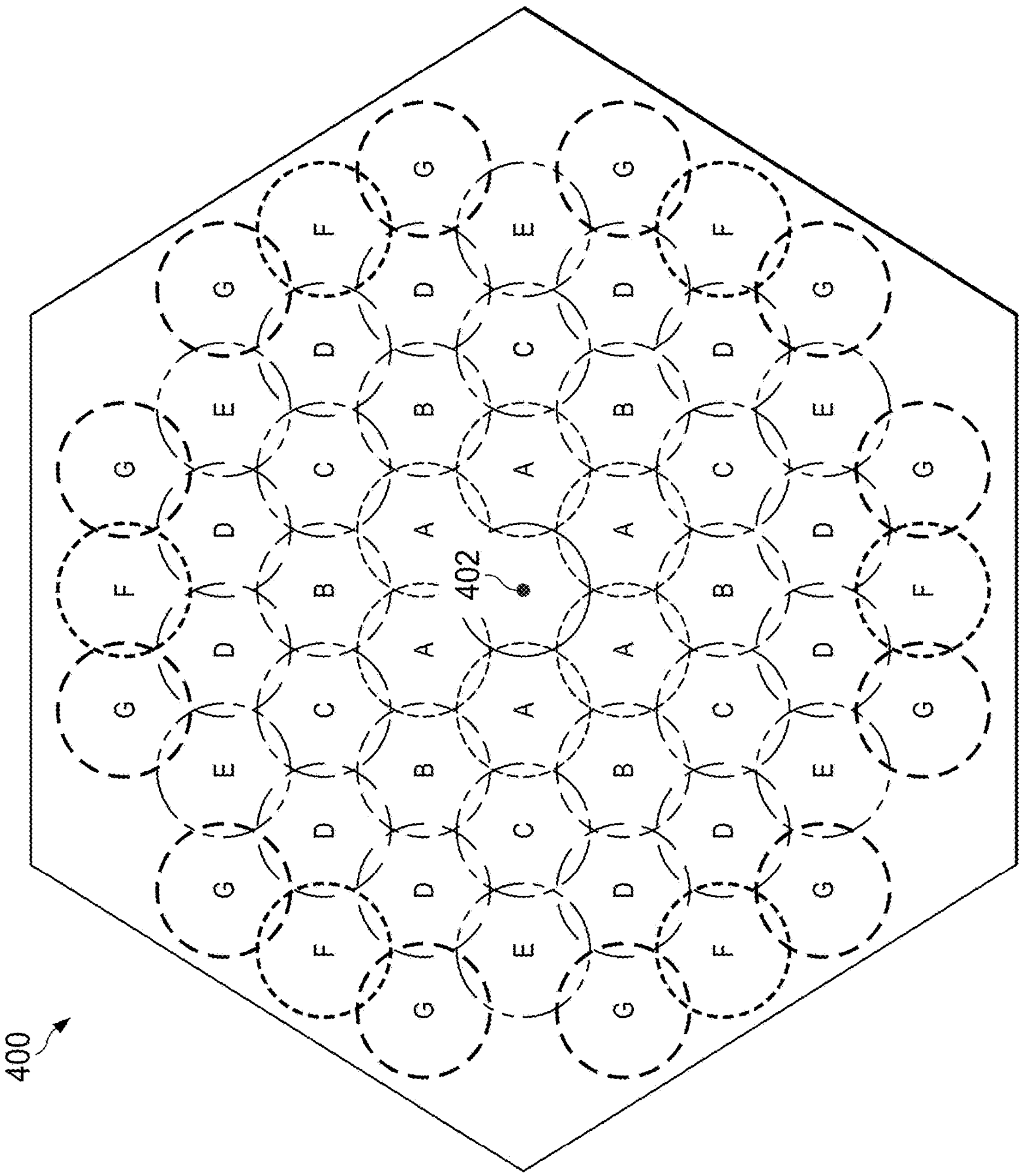


FIG. 4

500

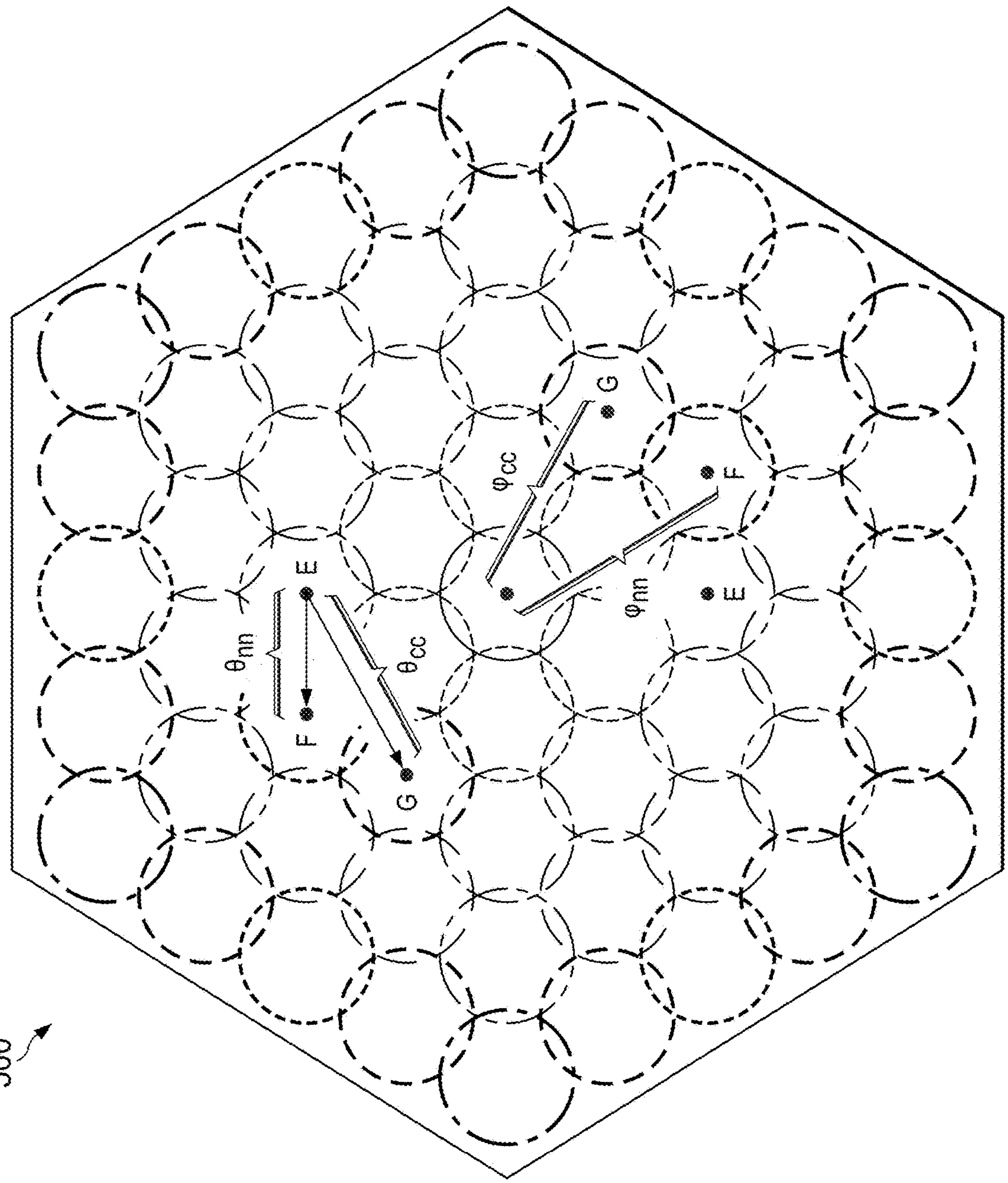


FIG. 5

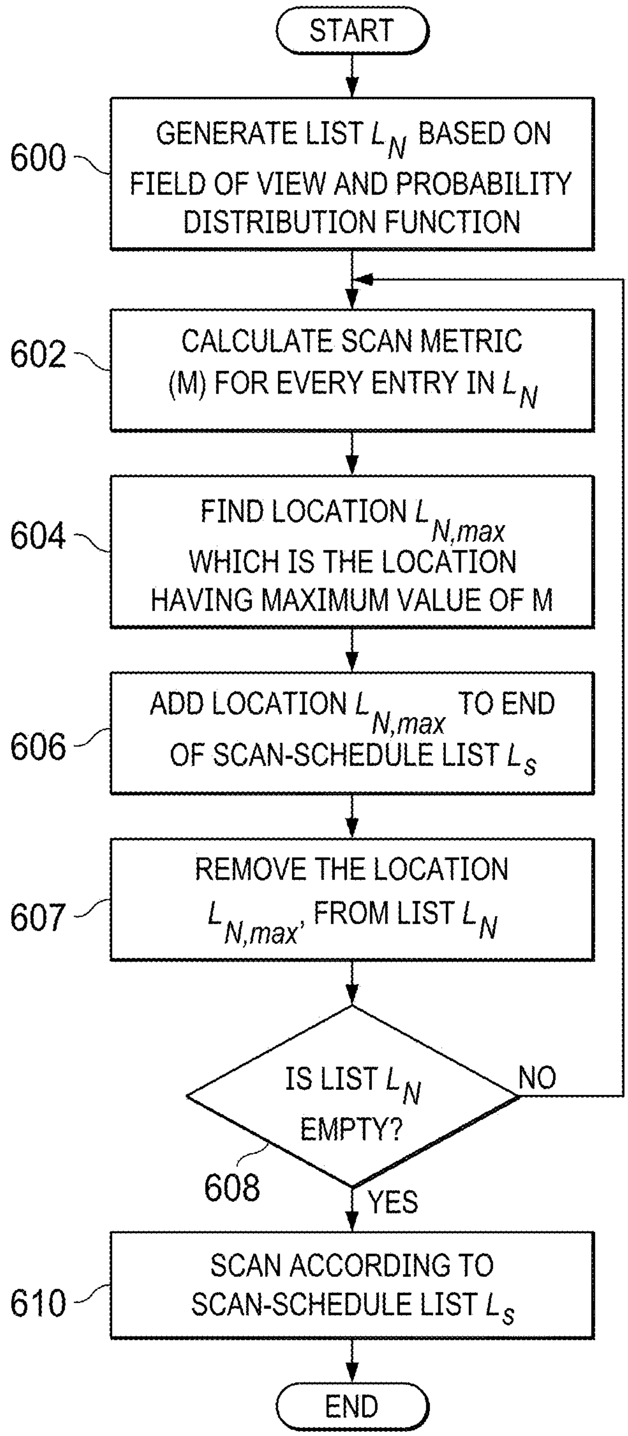

START
600
GENERATE LIST L_N BASED ON FIELD OF VIEW AND PROBABILITY DISTRIBUTION FUNCTION
602
CALCULATE SCAN METRIC (M) FOR EVERY ENTRY IN L_N
604
FIND LOCATION $L_{N,max}$ WHICH IS THE LOCATION HAVING MAXIMUM VALUE OF M
606
ADD LOCATION $L_{N,max}$ TO END OF SCAN-SCHEDULE LIST L_S
607
REMOVE THE LOCATION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

FIG. 6

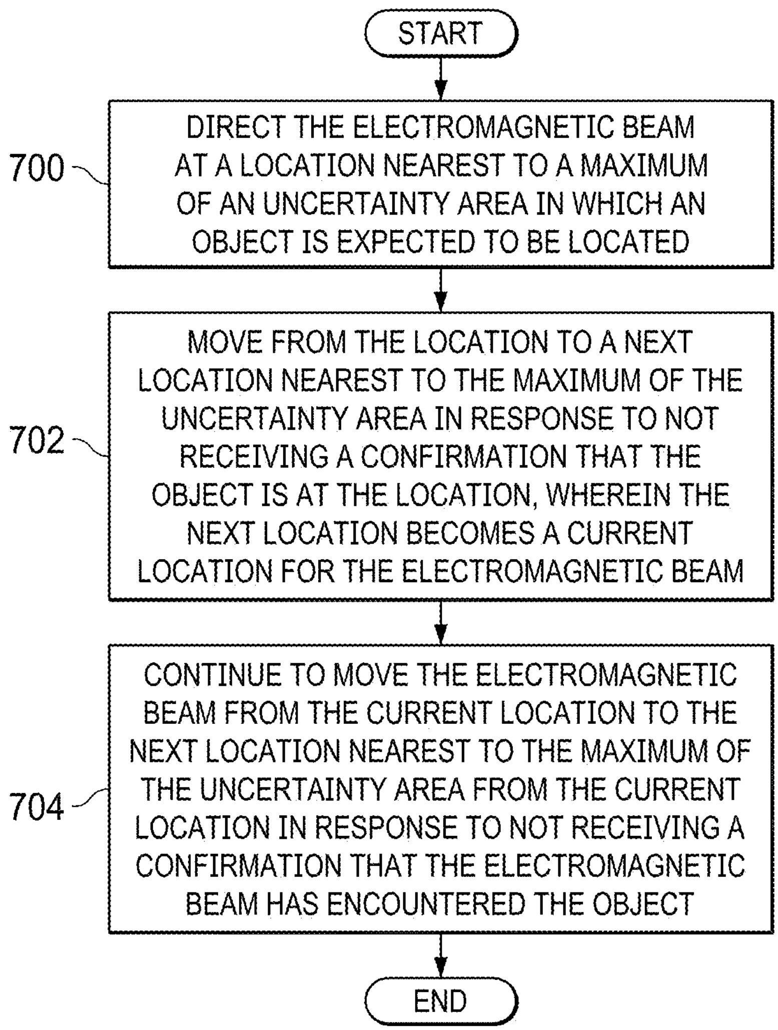

START
700
DIRECT THE ELECTROMAGNETIC BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH AN OBJECT IS EXPECTED TO BE LOCATED
702
MOVE FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE OBJECT IS 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

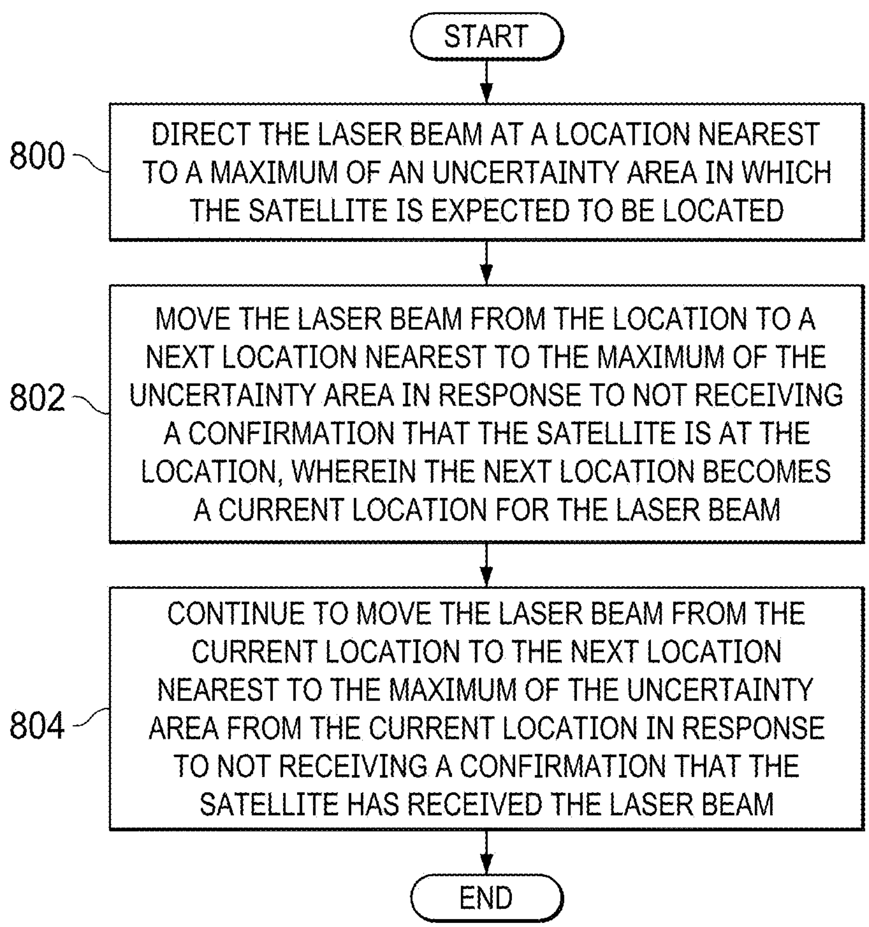

START
800
DIRECT THE LASER BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH THE SATELLITE IS EXPECTED TO BE LOCATED
802
MOVE THE LASER BEAM FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE 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

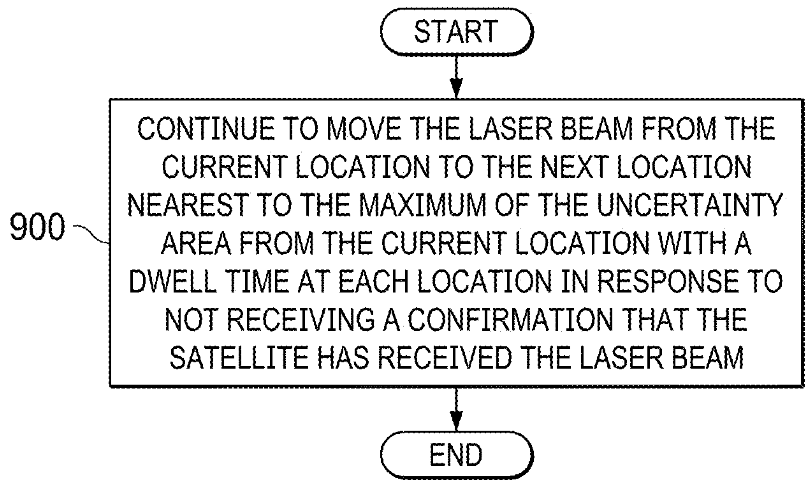

START
CONTINUE TO MOVE THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A DWELL TIME AT EACH LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
900
END

FIG. 9

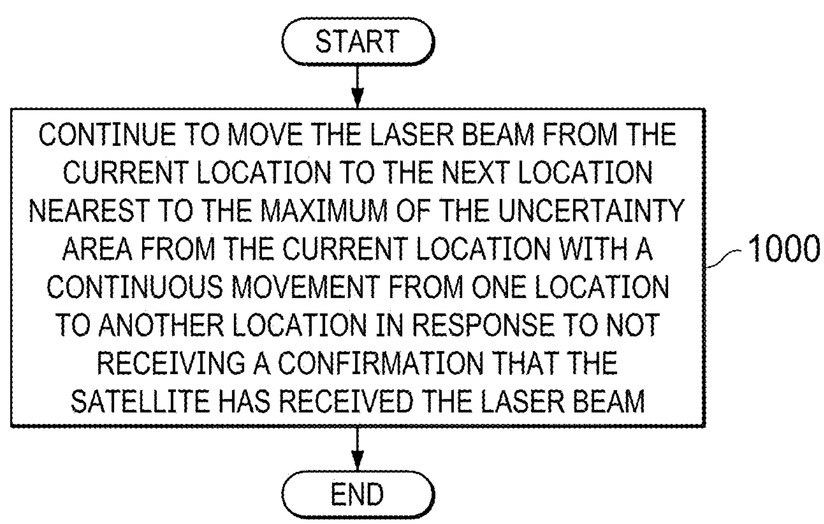

START
CONTINUE TO MOVE THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A CONTINUOUS MOVEMENT FROM ONE LOCATION TO ANOTHER LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE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

FIG. 10

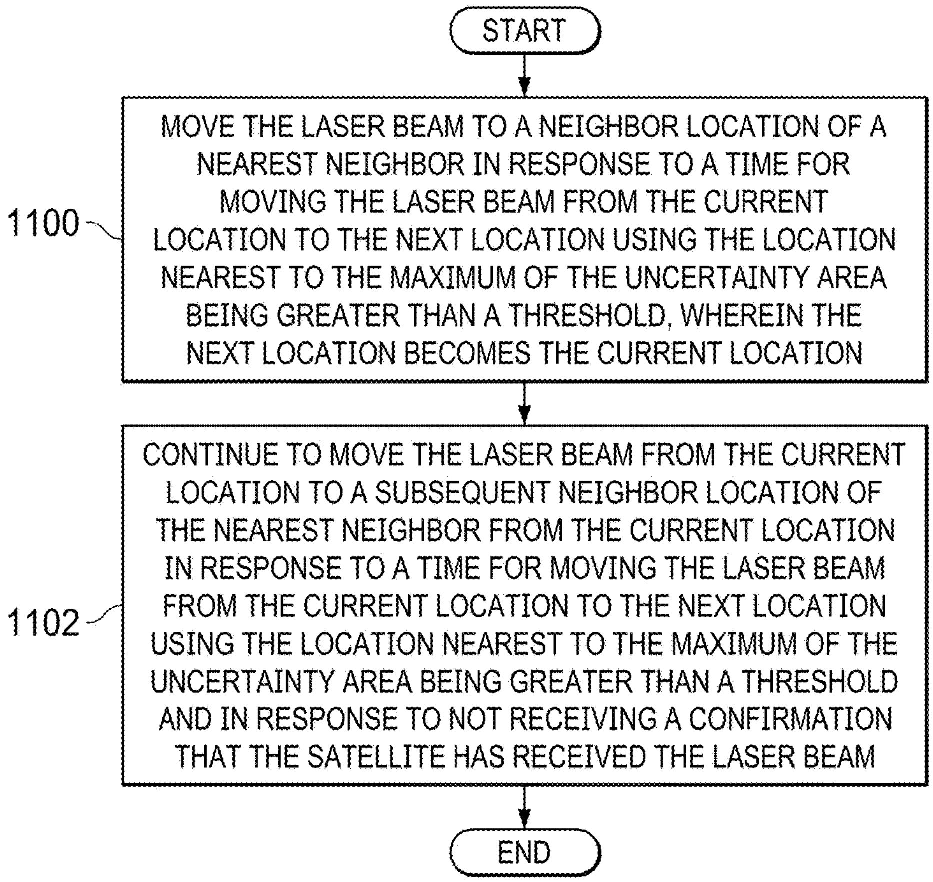

START
MOVE THE LASER BEAM TO A NEIGHBOR LOCATION OF A NEAREST NEIGHBOR IN RESPONSE TO A TIME FOR MOVING THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION USING THE LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA BEING GREATER THAN A THRESHOLD, WHEREIN THE NEXT LOCATION BECOMES THE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

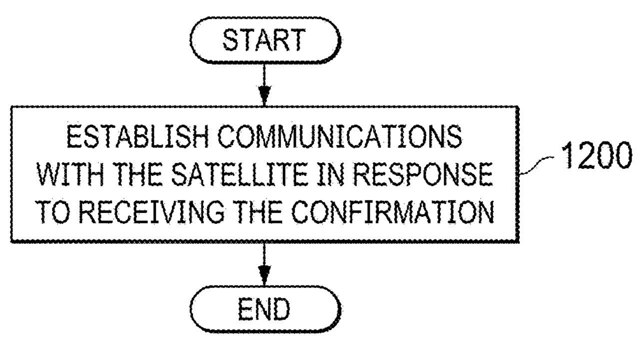

START
ESTABLISH COMMUNICATIONS WITH THE SATELLITE IN RESPONSE TO RECEIVING THE CONFIRMATION
1200
END

FIG. 12

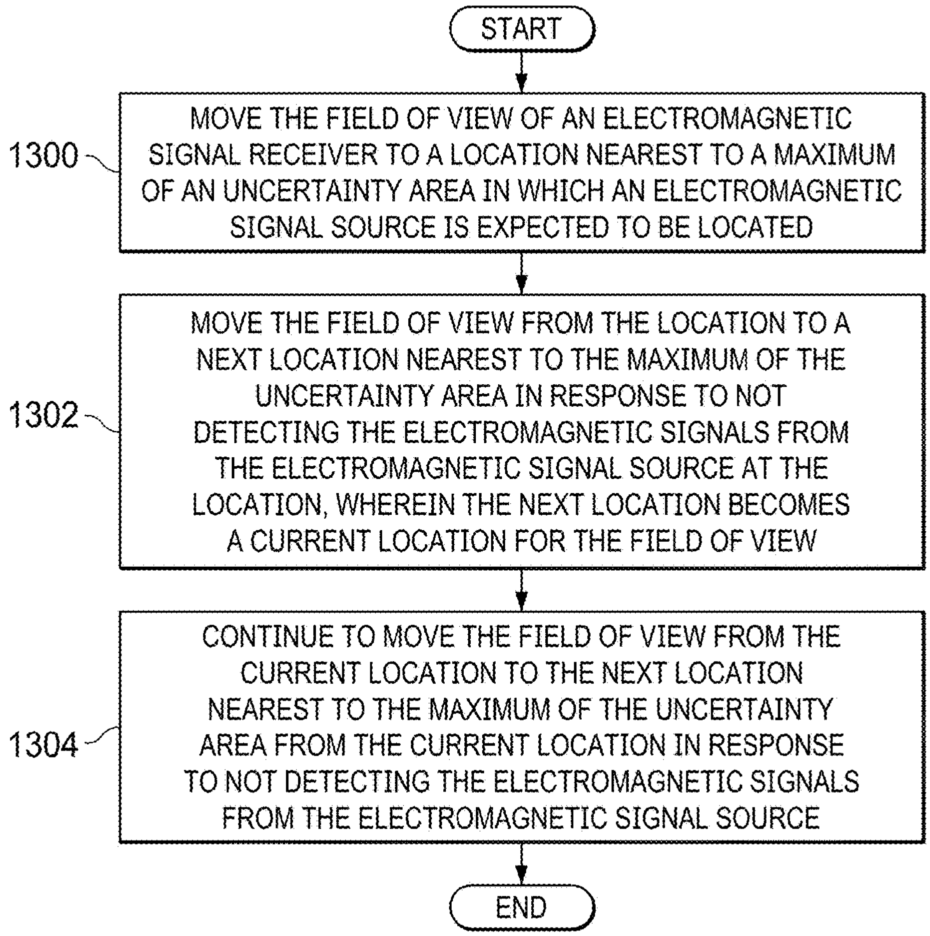

START
MOVE THE FIELD OF VIEW OF AN ELECTROMAGNETIC SIGNAL RECEIVER TO A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH AN ELECTROMAGNETIC SIGNAL SOURCE IS EXPECTED TO BE LOCATED
1300
MOVE THE FIELD OF VIEW FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA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

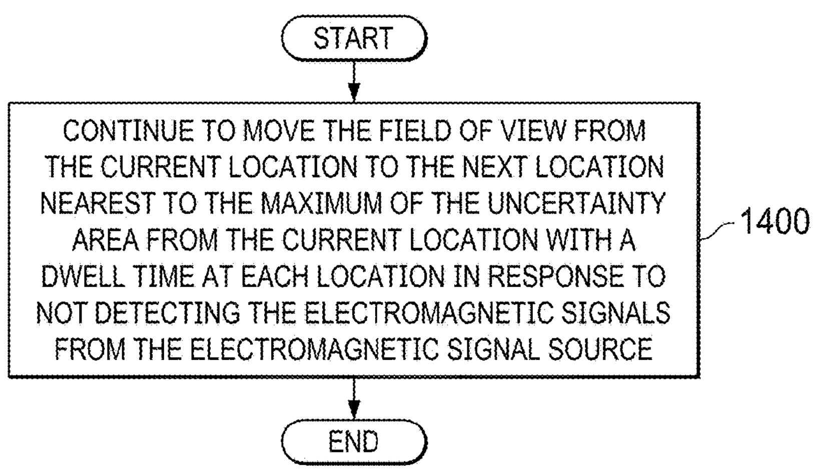

START
CONTINUE TO MOVE THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A DWELL TIME AT EACH LOCATION IN RESPONSE TO NOT DETECTING THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC SIGNAL SOURCE
1400
END

FIG. 14

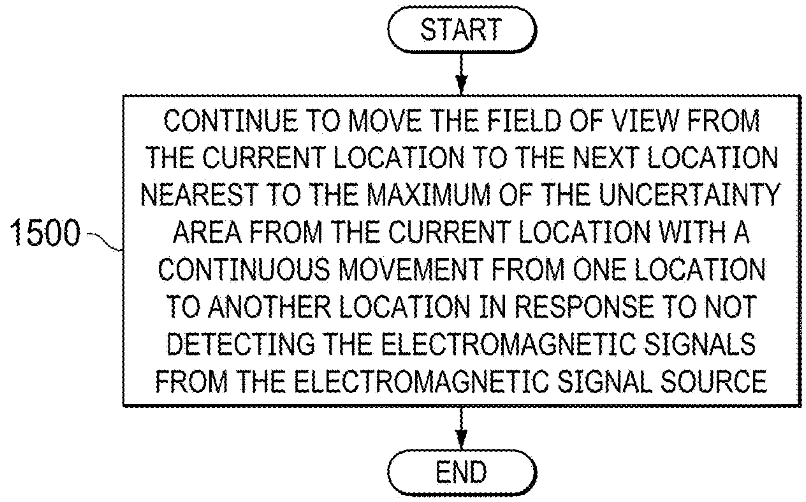

START
CONTINUE TO MOVE THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA FROM THE CURRENT LOCATION WITH A CONTINUOUS MOVEMENT FROM ONE LOCATION TO ANOTHER LOCATION IN RESPONSE TO NOT DETECTING THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC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

FIG. 15

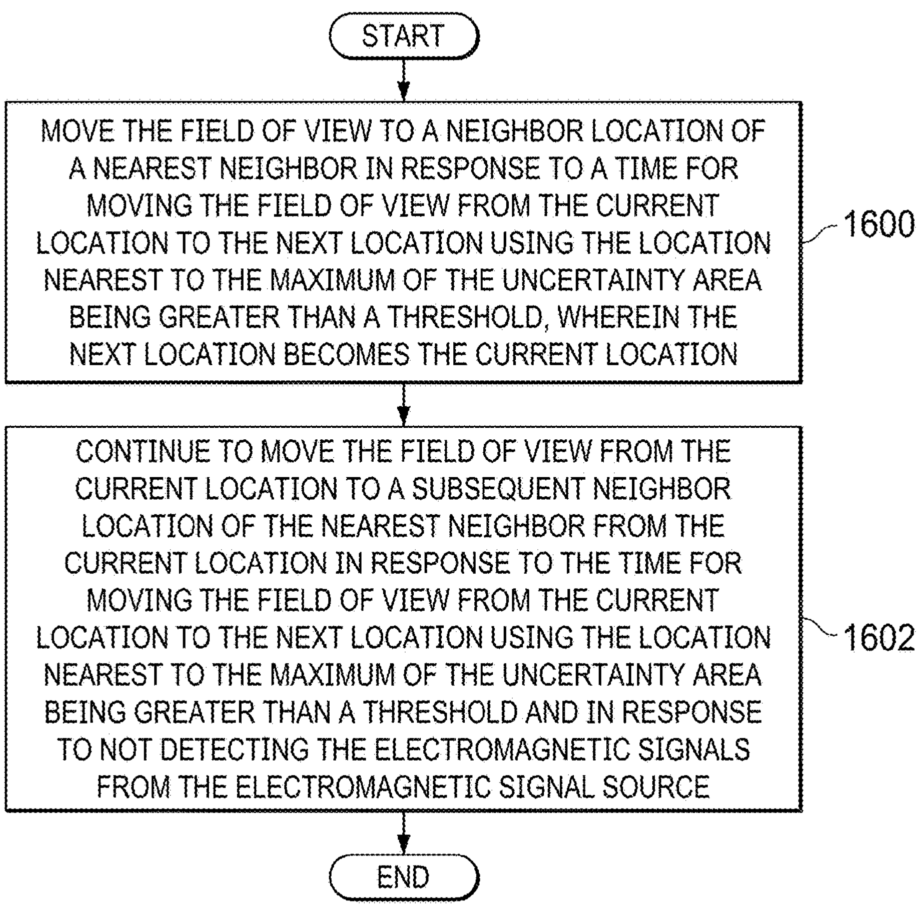

START
MOVE THE FIELD OF VIEW TO A NEIGHBOR LOCATION OF A NEAREST NEIGHBOR IN RESPONSE TO A TIME FOR MOVING THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION USING THE LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA BEING GREATER THAN A THRESHOLD, WHEREIN THE NEXT LOCATION BECOMES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

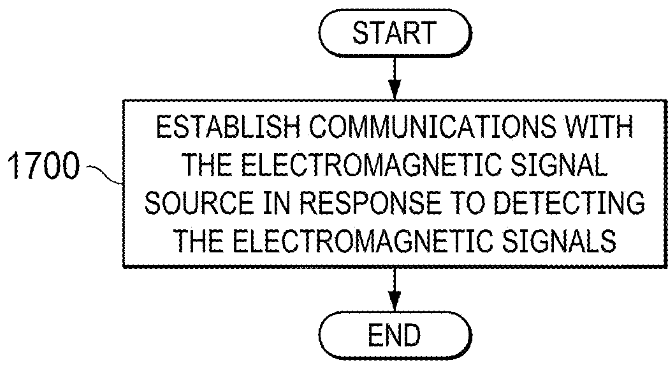

START
ESTABLISH COMMUNICATIONS WITH THE ELECTROMAGNETIC SIGNAL SOURCE IN RESPONSE TO DETECTING THE ELECTROMAGNETIC SIGNALS
1700
END

FIG. 17

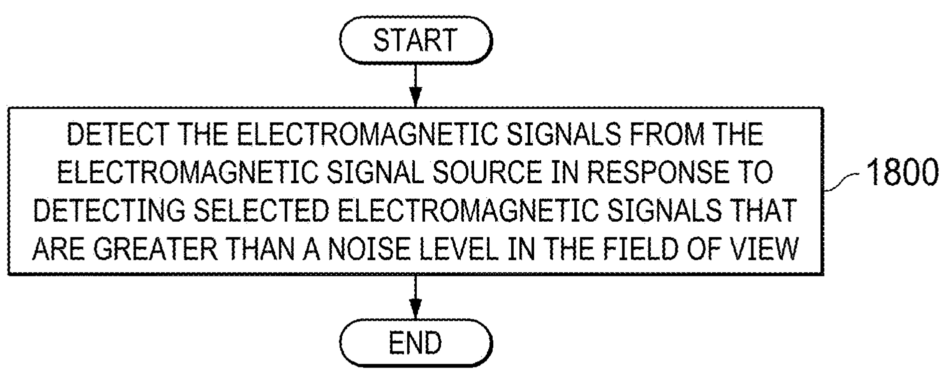

START
DETECT THE ELECTROMAGNETIC SIGNALS FROM THE ELECTROMAGNETIC SIGNAL SOURCE IN RESPONSE TO DETECTING SELECTED ELECTROMAGNETIC SIGNALS THAT ARE GREATER THAN A NOISE LEVEL IN THE FIELD OF VIEW
1800
END

FIG. 18

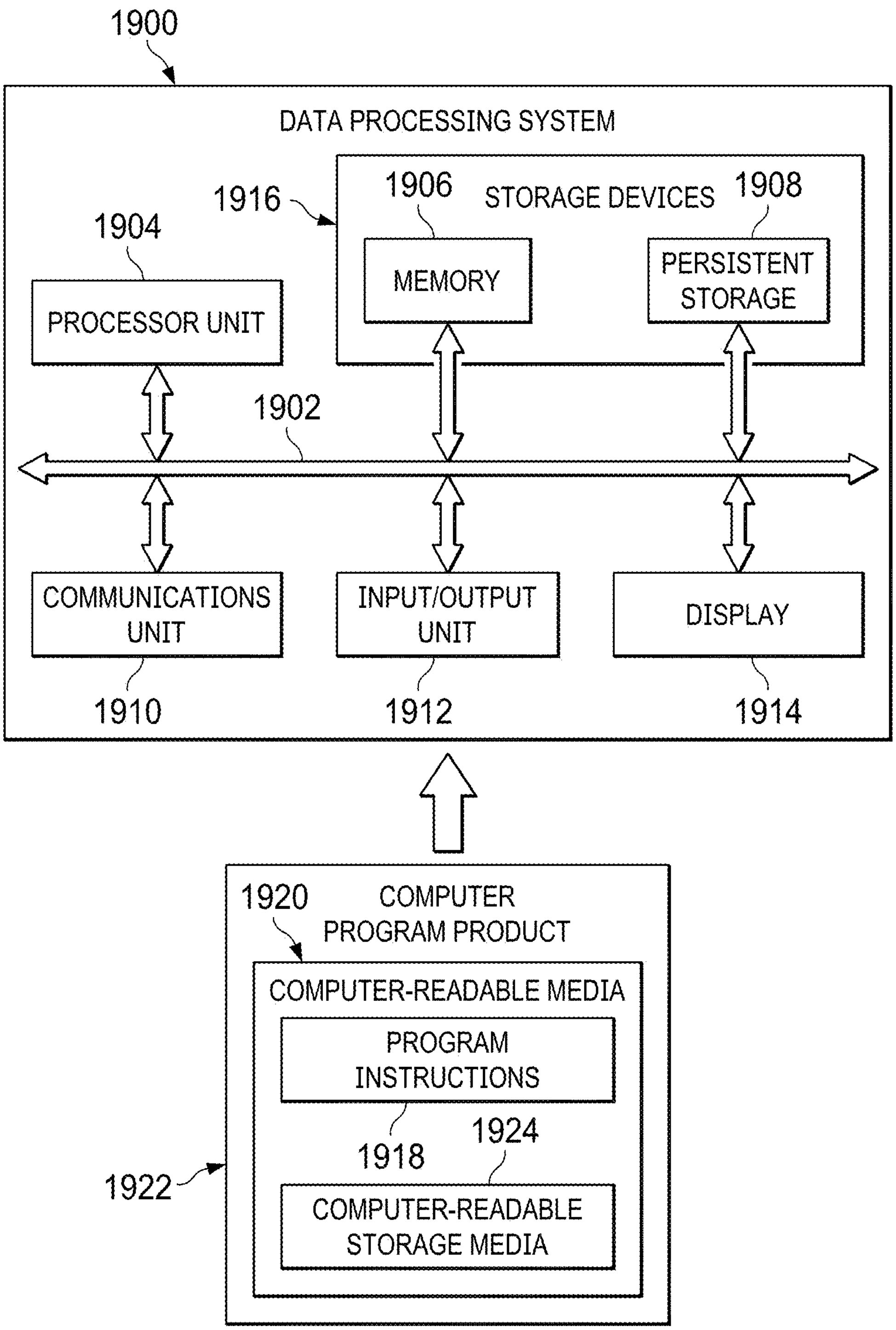
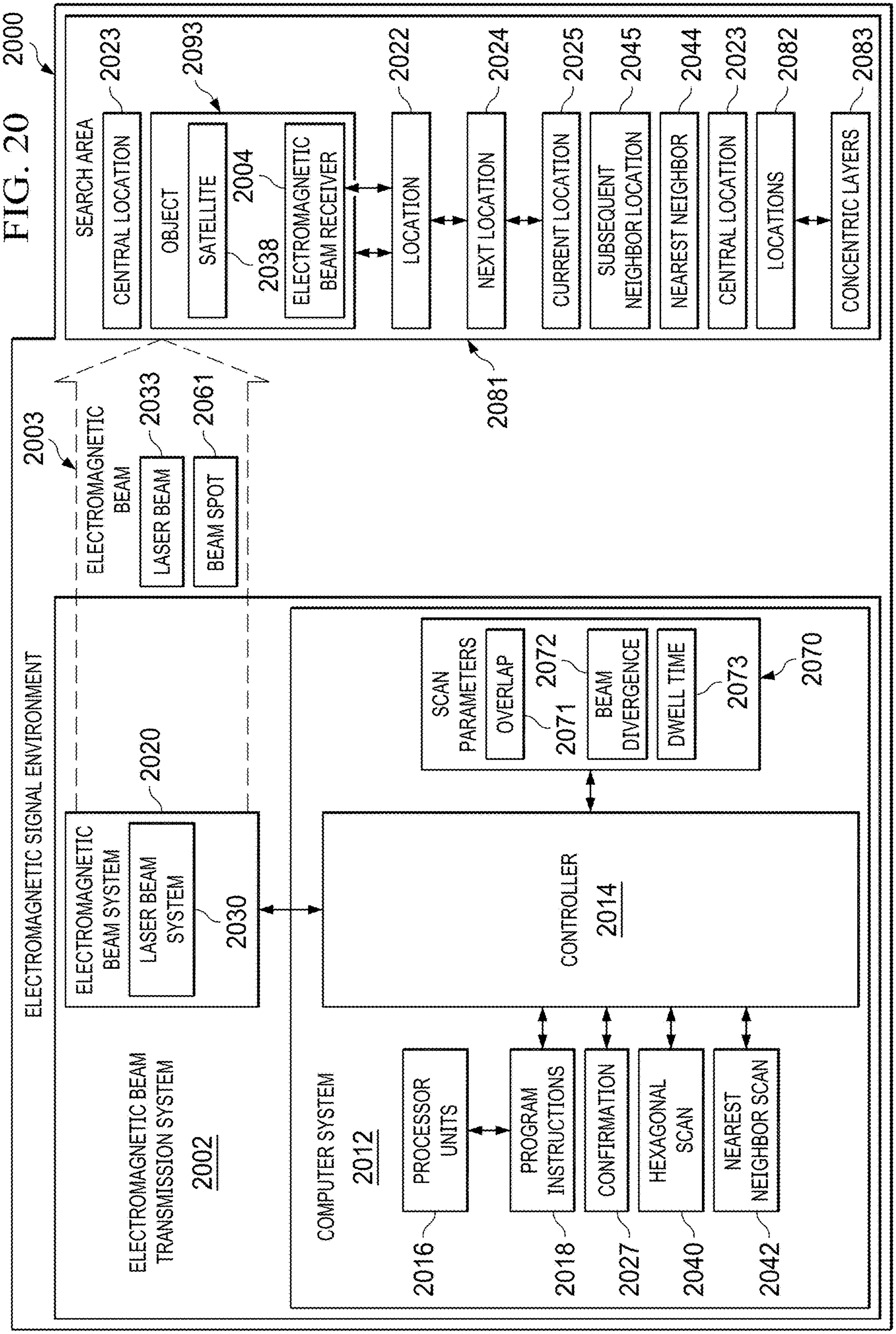

1900
DATA PROCESSING SYSTEM
1916
STORAGE DEVICES
1906
MEMORY
1908
PERSISTENT STORAGE
1904
PROCESSOR UNIT
1902
COMMUNICATIONS UNIT
INPUT/OUTPUT UNIT
DISPLAY
1910
1912
1914
1920
COMPUTER PROGRAM PRODUCT
COMPUTER-READABLE MEDIA
PROGRAM INSTRUCTIONS
1918
1924
1922
COMPUTER-READABLE STORAGE MEDIA

FIG. 19

FIG. 20


2000
ELECTROMAGNETIC SIGNAL ENVIRONMENT
ELECTROMAGNETIC BEAM TRANSMISSION SYSTEM
2002
ELECTROMAGNETIC BEAM SYSTEM
LASER BEAM SYSTEM
2030
2020
COMPUTER SYSTEM
2012
CONTROLLER
2014
SCAN PARAMETERS
OVERLAP
2071
BEAM DIVERGENCE
2072
DWELL TIME
2073
2070
PROCESSOR UNITS
2016
PROGRAM INSTRUCTIONS
2018
CONFIRMATION
2027
HEXAGONAL SCAN
2040
NEAREST NEIGHBOR SCAN
2042
ELECTROMAGNETIC BEAM
2003
LASER BEAM
2033
BEAM SPOT
2061
SEARCH AREA
2081
CENTRAL LOCATION
2023
OBJECT
2093
SATELLITE
2038
ELECTROMAGNETIC BEAM RECEIVER
2004
LOCATION
2022
NEXT LOCATION
2024
CURRENT LOCATION
2025
SUBSEQUENT NEIGHBOR LOCATION
2045
NEAREST NEIGHBOR
2044
CENTRAL LOCATION
2023
LOCATIONS
2082
CONCENTRIC LAYERS
2083

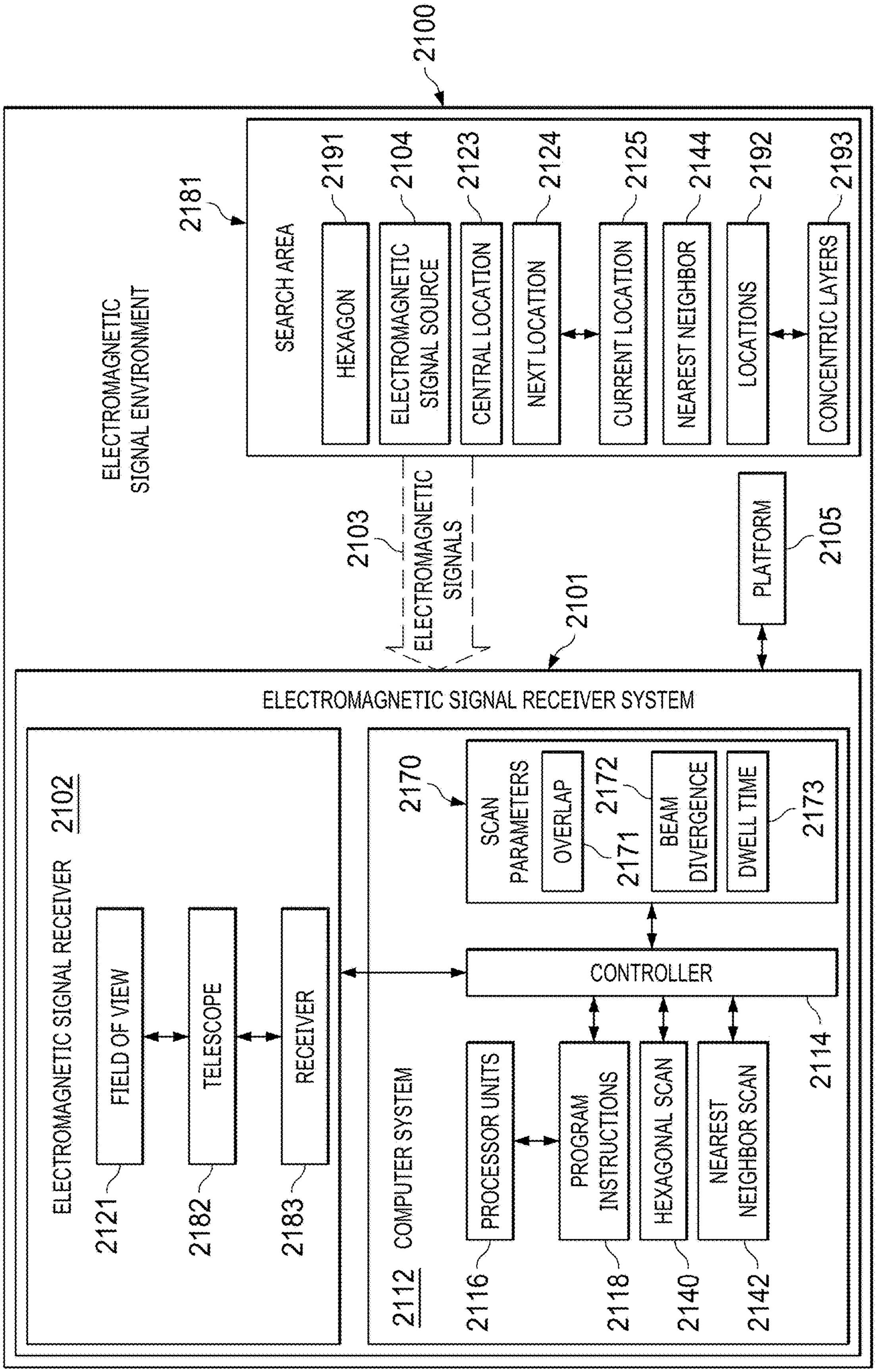

2100
ELECTROMAGNETIC SIGNAL ENVIRONMENT
2181
SEARCH AREA
HEXAGON
2191
ELECTROMAGNETIC SIGNAL SOURCE
2104
CENTRAL LOCATION
2123
NEXT LOCATION
2124
CURRENT LOCATION
2125
NEAREST NEIGHBOR
2144
LOCATIONS
2192
CONCENTRIC LAYERS
2193
ELECTROMAGNETIC SIGNALS
2103
PLATFORM
2105
2101
ELECTROMAGNETIC SIGNAL RECEIVER SYSTEM
ELECTROMAGNETIC SIGNAL RECEIVER 2102
FIELD OF VIEW
2121
TELESCOPE
2182
RECEIVER
2183
2112 COMPUTER SYSTEM
SCAN PARAMETERS
2170
OVERLAP
2171
BEAM DIVERGENCE
2172
DWELL TIME
2173
CONTROLLER
2114
PROCESSOR UNITS
2116
PROGRAM INSTRUCTIONS
2118
HEXAGONAL SCAN
2140
NEAREST NEIGHBOR SCAN
2142

FIG. 21

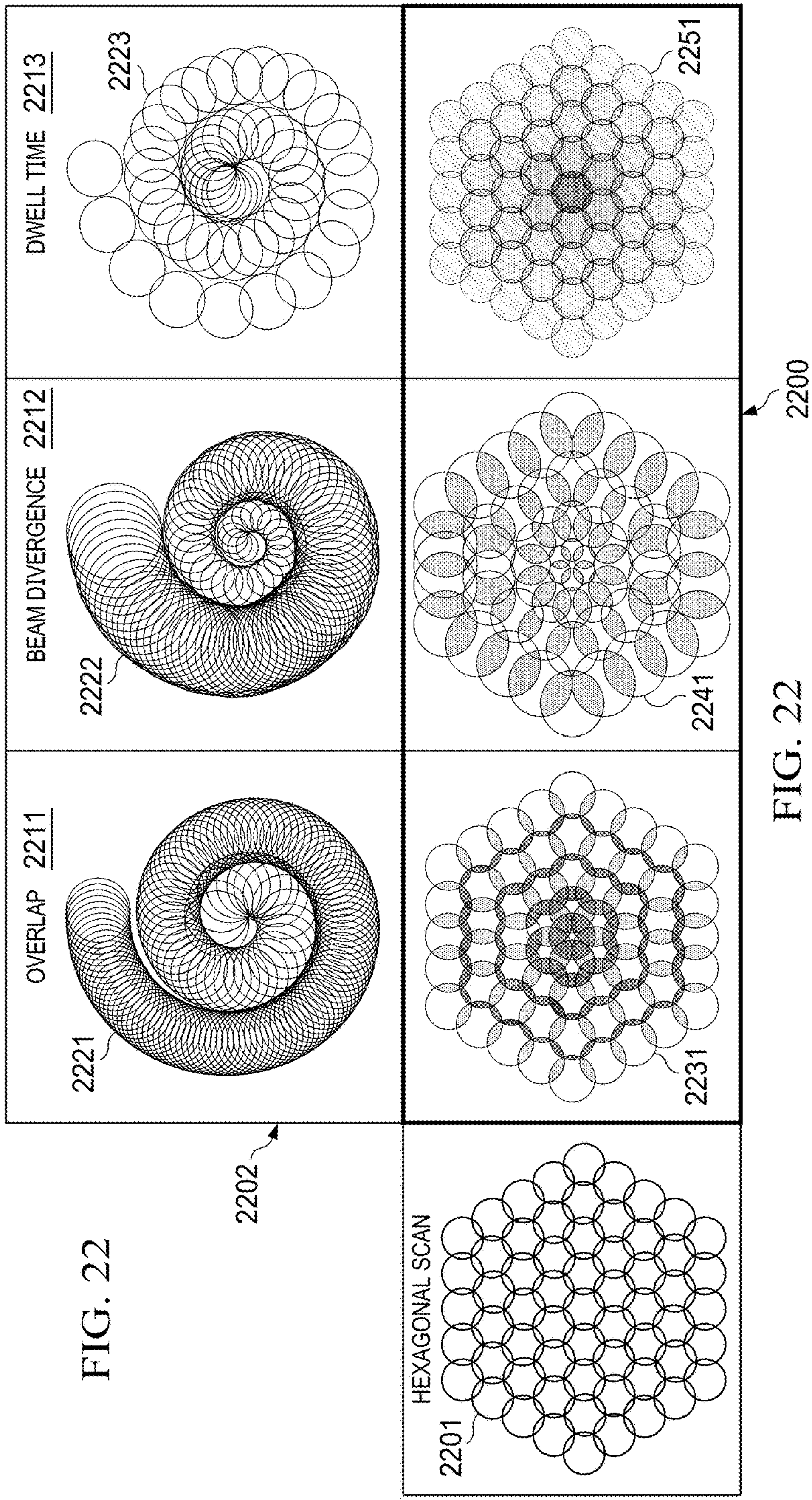

OVERLAP 2211
2221
BEAM DIVERGENCE 2212
2222
DWELL TIME 2213
2223
2202
HEXAGONAL SCAN
2201
2231
2241
2251
2200

FIG. 22

FIG. 22

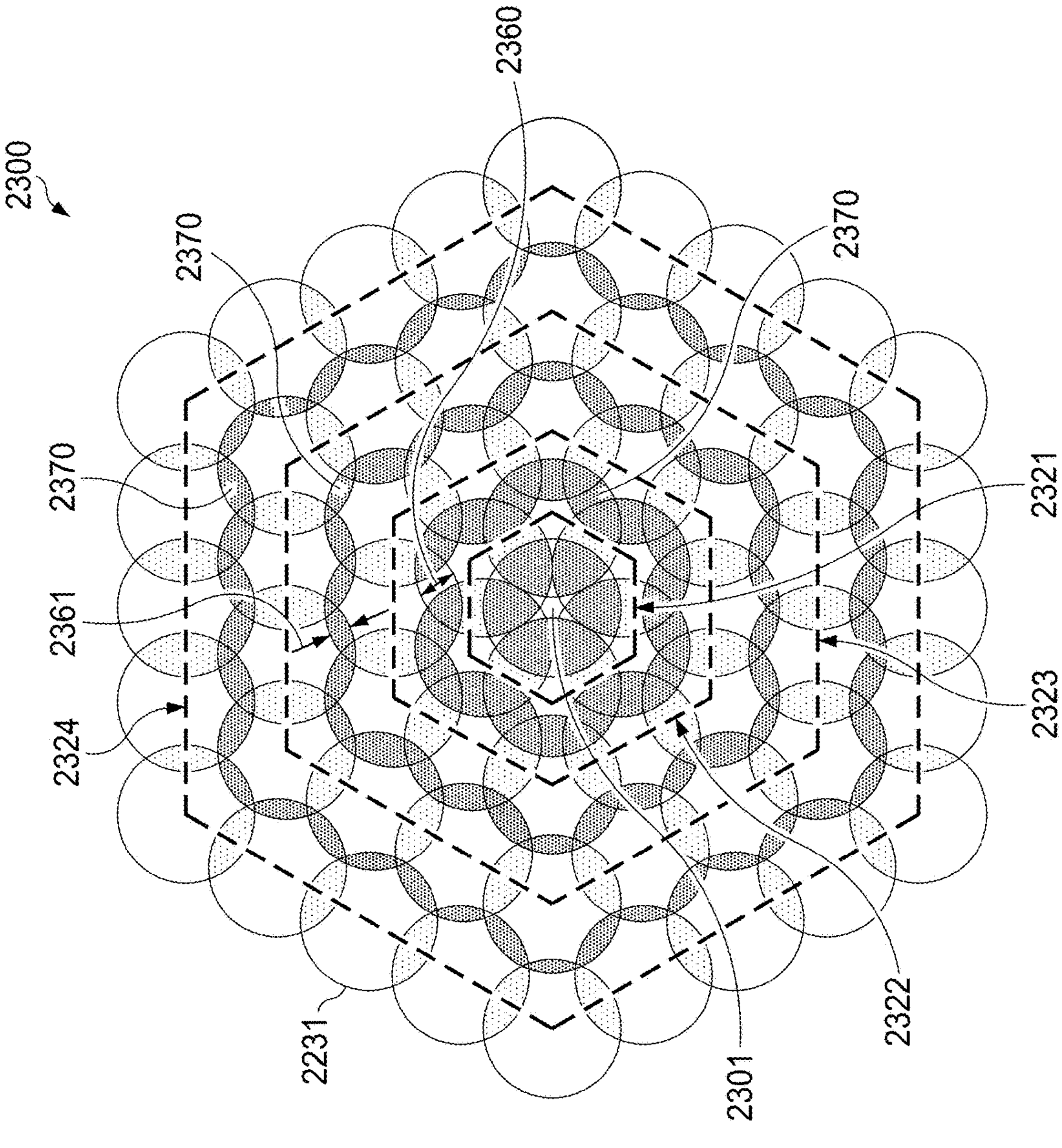


FIG. 23

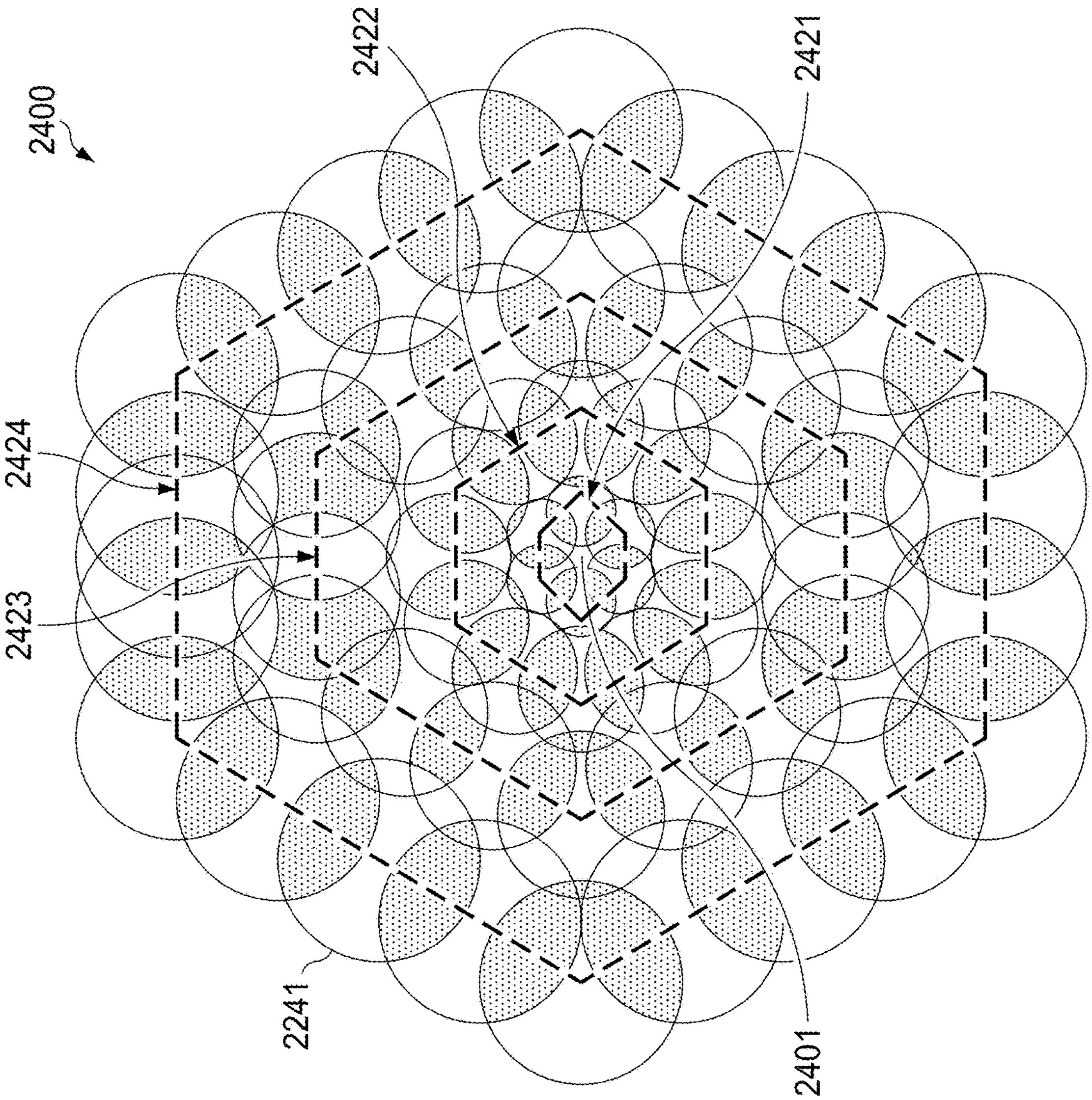


FIG. 24

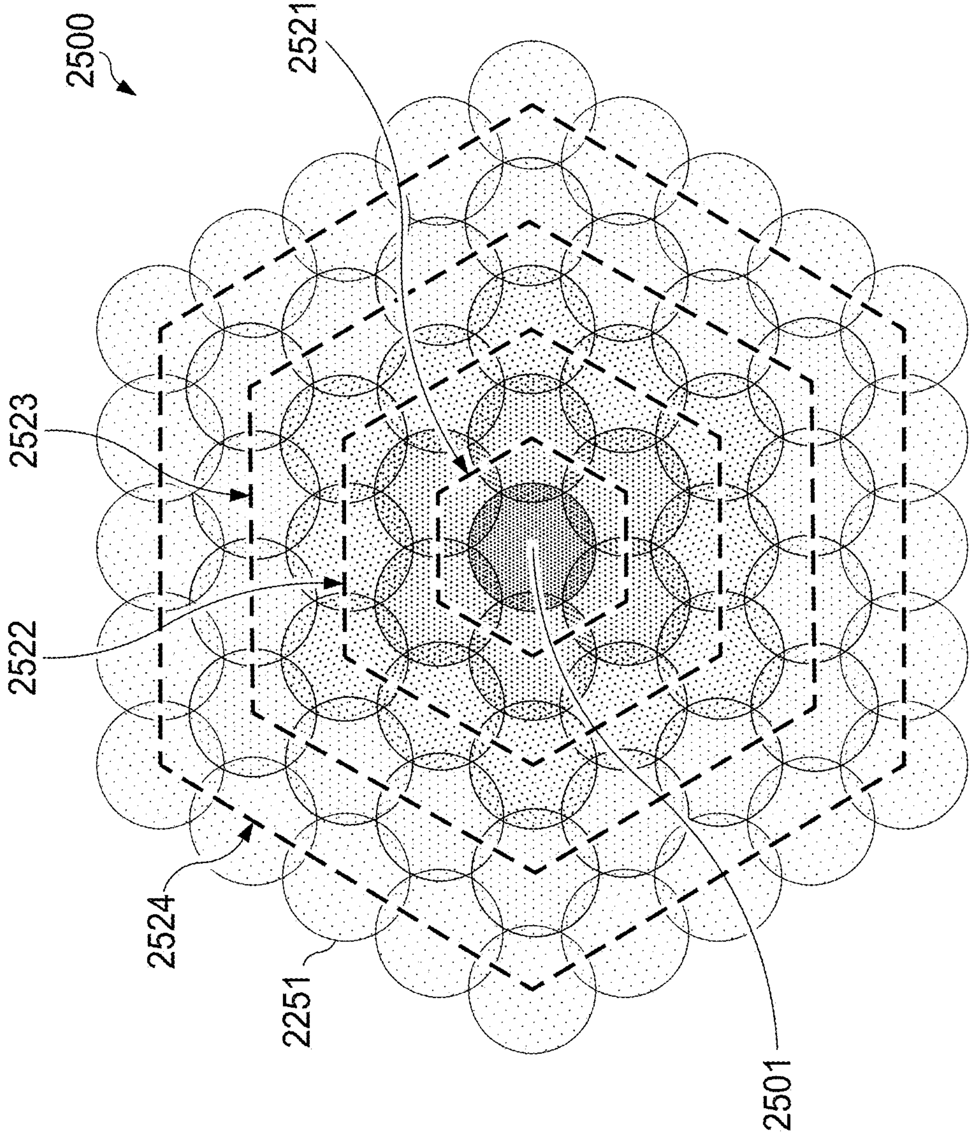


FIG. 25

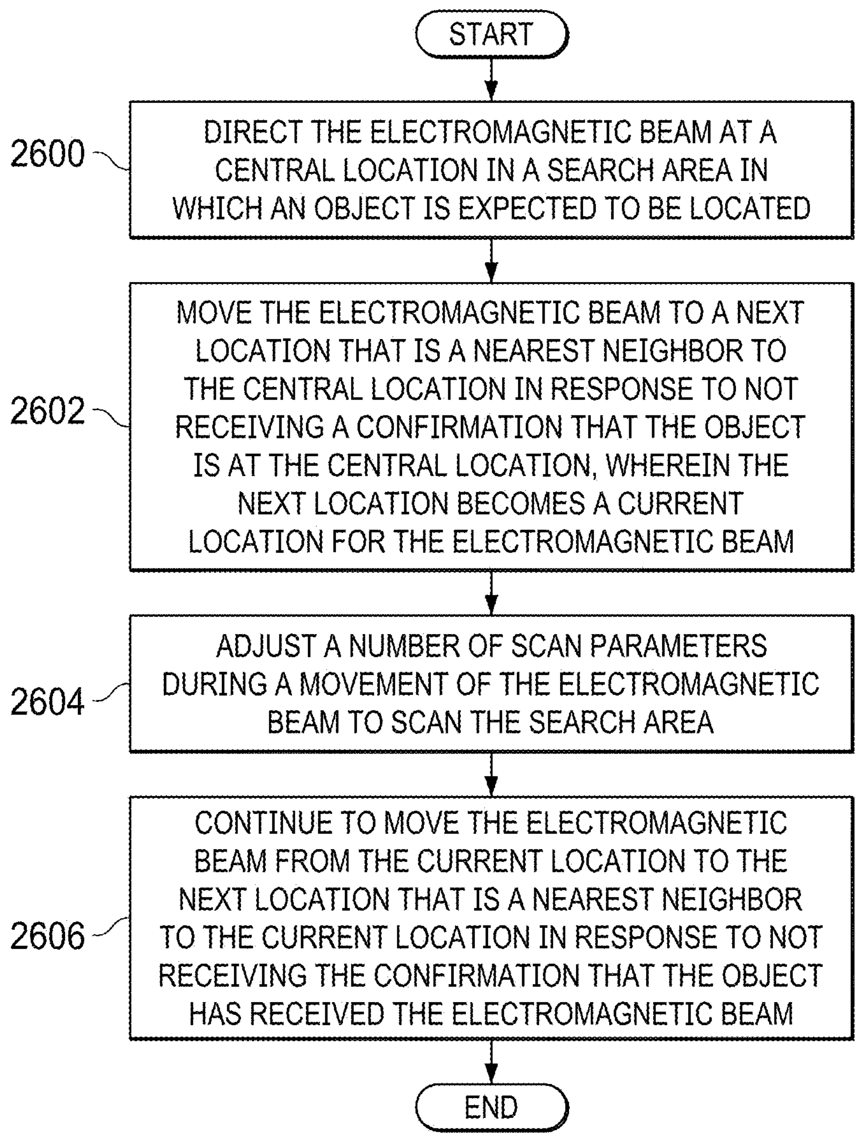

START
2600
DIRECT THE ELECTROMAGNETIC BEAM AT A CENTRAL LOCATION IN A SEARCH AREA IN WHICH AN OBJECT IS EXPECTED TO BE LOCATED
2602
MOVE THE ELECTROMAGNETIC BEAM TO A NEXT LOCATION THAT IS A NEAREST NEIGHBOR TO THE CENTRAL LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE OBJECT IS AT THE CENTRAL LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE ELECTROMAGNETIC BEAM
2604
ADJUST A NUMBER OF SCAN PARAMETERS DURING A MOVEMENT OF THE ELECTROMAGNETIC BEAM TO SCAN THE SEARCH AREA
2606
CONTINUE TO MOVE THE ELECTROMAGNETIC BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION THAT IS A NEAREST NEIGHBOR TO THE CURRENT LOCATION IN RESPONSE TO NOT RECEIVING THE CONFIRMATION THAT THE OBJECT HAS RECEIVED THE ELECTROMAGNETIC BEAM
END

FIG. 26

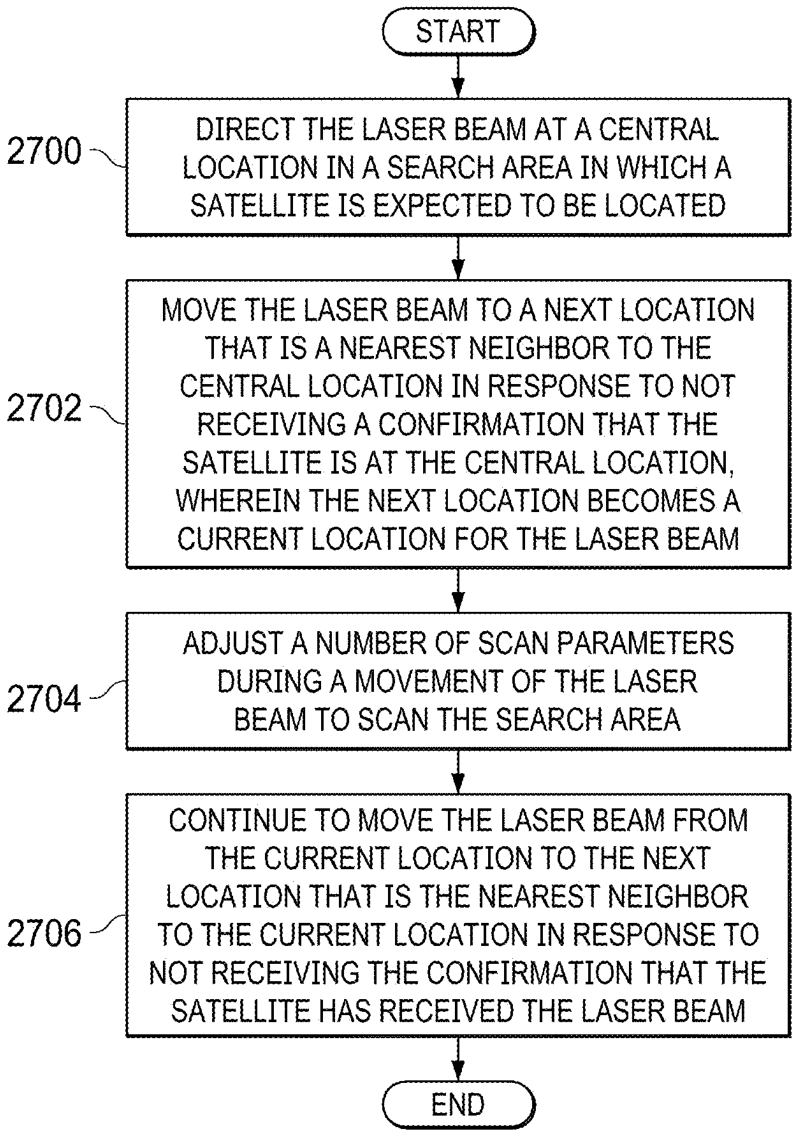

START
2700
DIRECT THE LASER BEAM AT A CENTRAL LOCATION IN A SEARCH AREA IN WHICH A SATELLITE IS EXPECTED TO BE LOCATED
2702
MOVE THE LASER BEAM TO A NEXT LOCATION THAT IS A NEAREST NEIGHBOR TO THE CENTRAL LOCATION IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE IS AT THE CENTRAL LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE LASER BEAM
2704
ADJUST A NUMBER OF SCAN PARAMETERS DURING A MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA
2706
CONTINUE TO MOVE THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION THAT IS THE NEAREST NEIGHBOR TO THE CURRENT LOCATION IN RESPONSE TO NOT RECEIVING THE CONFIRMATION THAT THE SATELLITE HAS RECEIVED THE LASER BEAM
END

FIG. 27

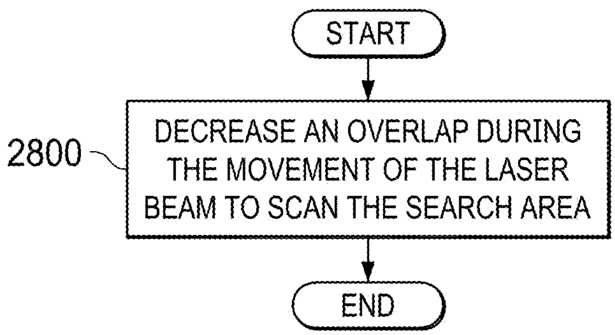

START
DECREASE AN OVERLAP DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA
2800
END

FIG. 28

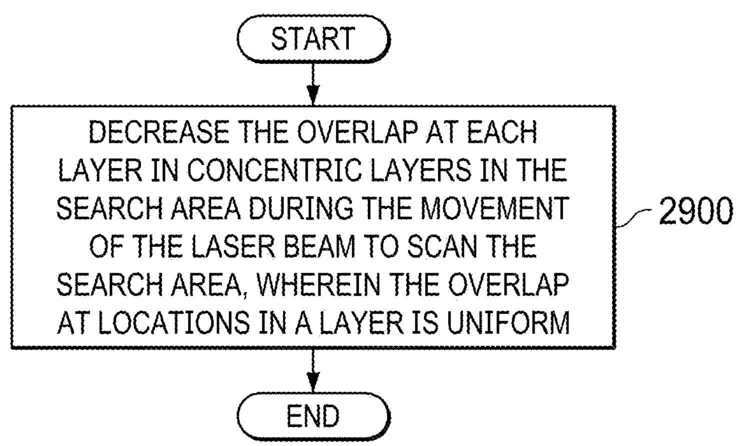

START
DECREASE THE OVERLAP AT EACH LAYER IN CONCENTRIC LAYERS IN THE SEARCH AREA DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA, WHEREIN THE OVERLAP AT LOCATIONS IN A LAYER IS UNIFORM
2900
END

FIG. 29

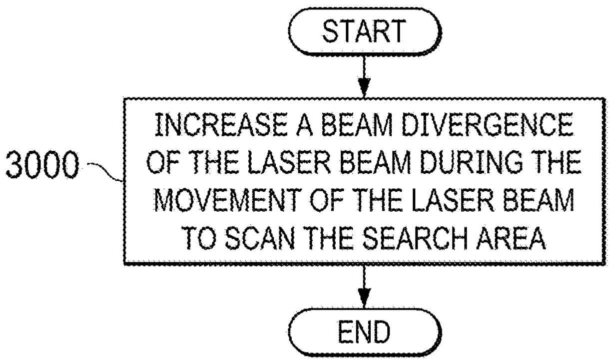

START
INCREASE A BEAM DIVERGENCE OF THE LASER BEAM DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA
3000
END

FIG. 30

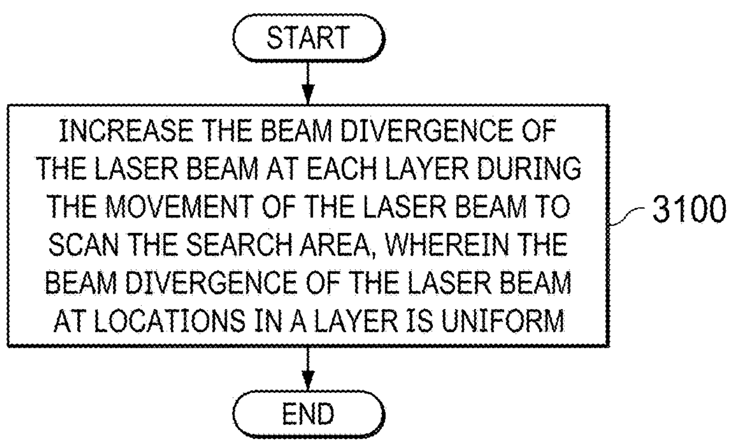

START
INCREASE THE BEAM DIVERGENCE OF THE LASER BEAM AT EACH LAYER DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA, WHEREIN THE BEAM DIVERGENCE OF THE LASER BEAM AT LOCATIONS IN A LAYER IS UNIFORM
3100
END

FIG. 31

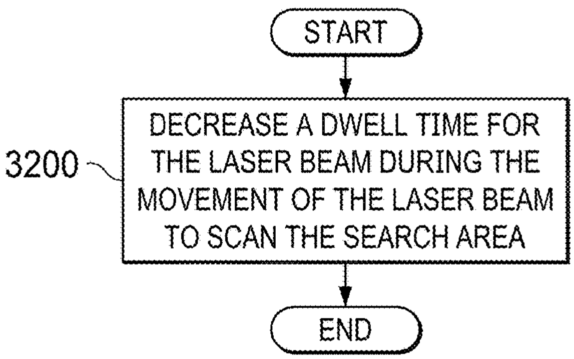

START
DECREASE A DWELL TIME FOR THE LASER BEAM DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA
3200
END

FIG. 32

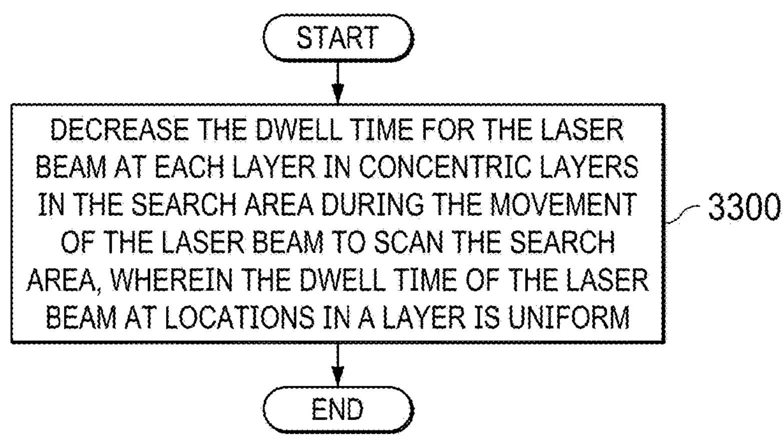

START
DECREASE THE DWELL TIME FOR THE LASER BEAM AT EACH LAYER IN CONCENTRIC LAYERS IN THE SEARCH AREA DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE SEARCH AREA, WHEREIN THE DWELL TIME OF THE LASER BEAM AT LOCATIONS IN A LAYER IS UNIFORM
3300
END

FIG. 33

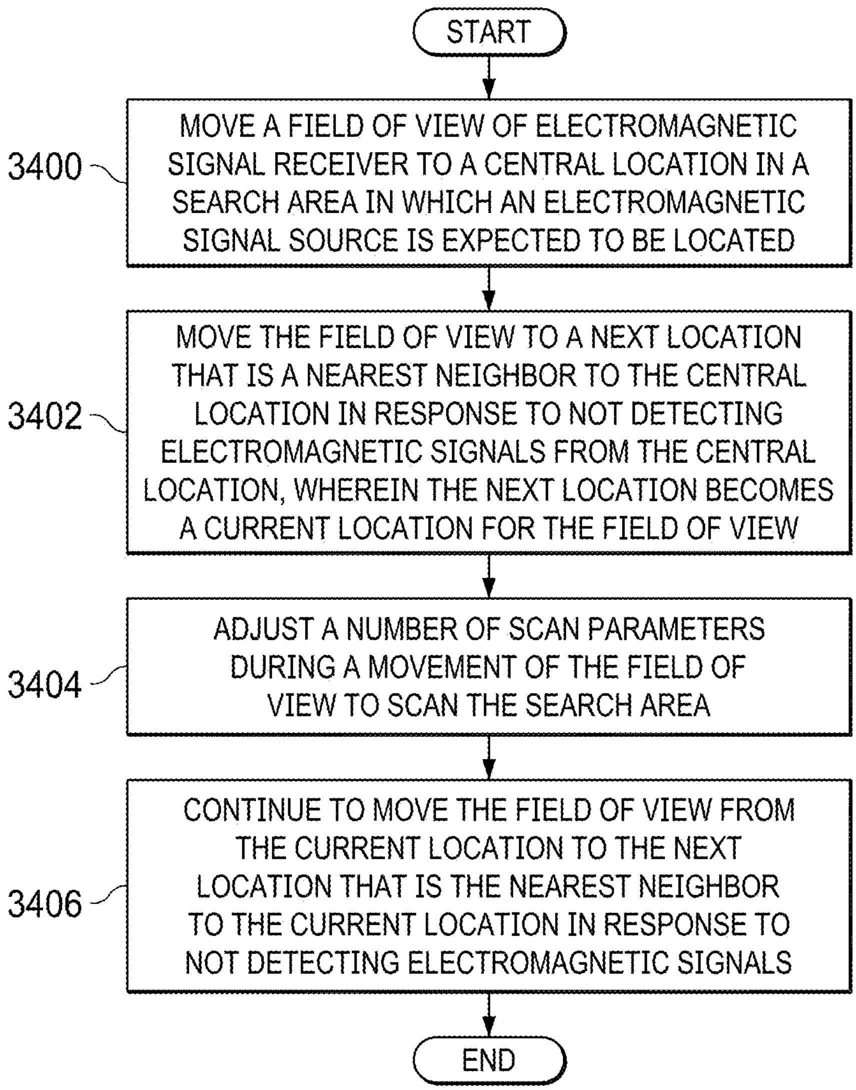

START
3400
MOVE A FIELD OF VIEW OF ELECTROMAGNETIC SIGNAL RECEIVER TO A CENTRAL LOCATION IN A SEARCH AREA IN WHICH AN ELECTROMAGNETIC SIGNAL SOURCE IS EXPECTED TO BE LOCATED
3402
MOVE THE FIELD OF VIEW TO A NEXT LOCATION THAT IS A NEAREST NEIGHBOR TO THE CENTRAL LOCATION IN RESPONSE TO NOT DETECTING ELECTROMAGNETIC SIGNALS FROM THE CENTRAL LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE FIELD OF VIEW
3404
ADJUST A NUMBER OF SCAN PARAMETERS DURING A MOVEMENT OF THE FIELD OF VIEW TO SCAN THE SEARCH AREA
3406
CONTINUE TO MOVE THE FIELD OF VIEW FROM THE CURRENT LOCATION TO THE NEXT LOCATION THAT IS THE NEAREST NEIGHBOR TO THE CURRENT LOCATION IN RESPONSE TO NOT DETECTING ELECTROMAGNETIC SIGNALS
END

FIG. 34

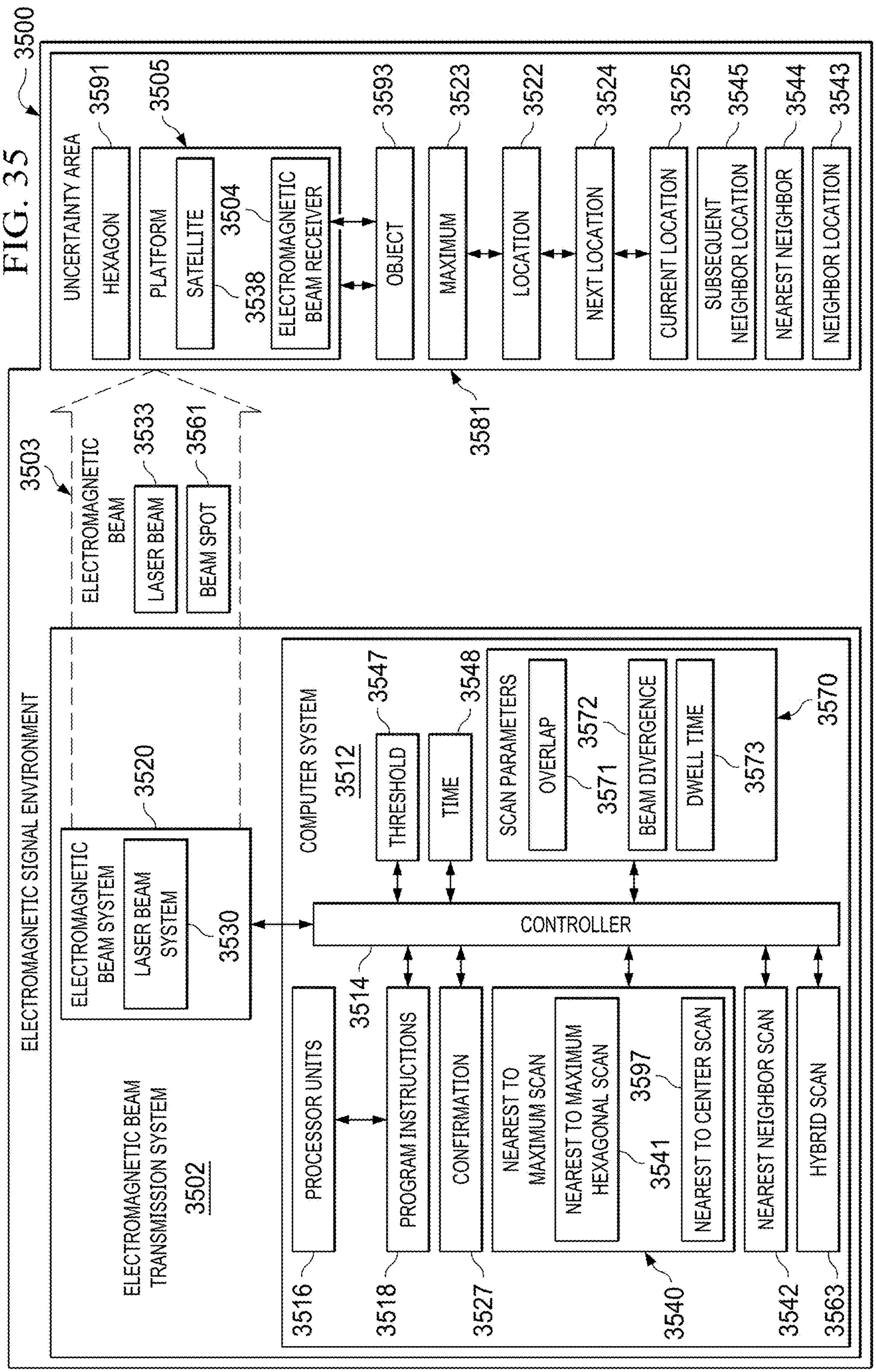

3500
ELECTROMAGNETIC SIGNAL ENVIRONMENT
ELECTROMAGNETIC BEAM TRANSMISSION SYSTEM
3502
ELECTROMAGNETIC BEAM SYSTEM
LASER BEAM SYSTEM
3530
3520
COMPUTER SYSTEM
3512
CONTROLLER
3514
THRESHOLD
3547
TIME
3548
SCAN PARAMETERS
OVERLAP
3571
3572
BEAM DIVERGENCE
DWELL TIME
3573
3570
PROCESSOR UNITS
3516
PROGRAM INSTRUCTIONS
3518
CONFIRMATION
3527
NEAREST TO MAXIMUM SCAN
NEAREST TO MAXIMUM HEXAGONAL SCAN
3541
NEAREST TO CENTER SCAN
3597
3540
NEAREST NEIGHBOR SCAN
3542
HYBRID SCAN
3563
ELECTROMAGNETIC BEAM
3503
LASER BEAM
3533
BEAM SPOT
3561
UNCERTAINTY AREA
HEXAGON
3591
PLATFORM
3505
SATELLITE
3538
ELECTROMAGNETIC BEAM RECEIVER
3504
OBJECT
3593
MAXIMUM
3523
LOCATION
3522
NEXT LOCATION
3524
CURRENT LOCATION
3525
SUBSEQUENT NEIGHBOR LOCATION
3545
NEAREST NEIGHBOR
3544
NEIGHBOR LOCATION
3543
3581

FIG. 35

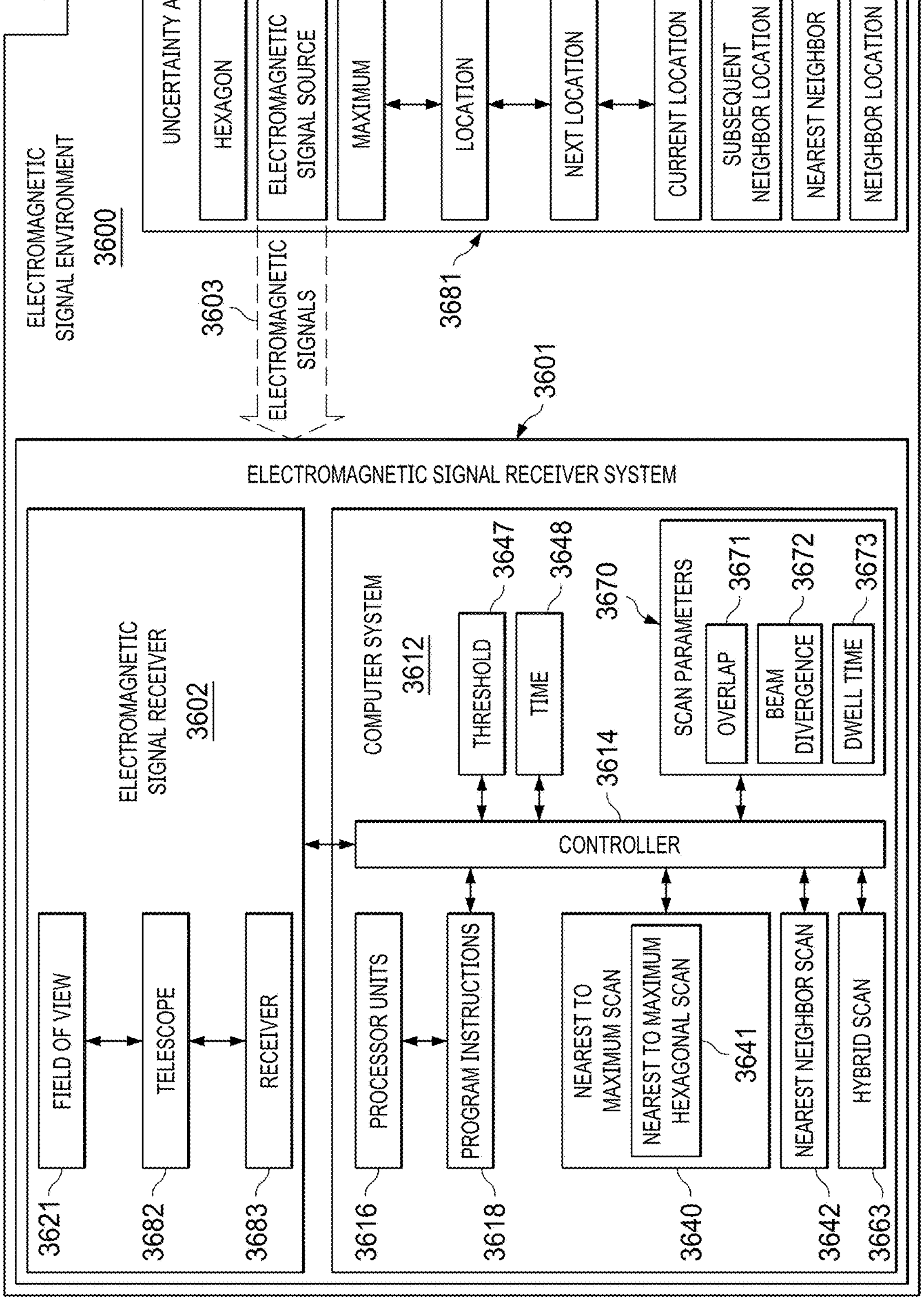

ELECTROMAGNETIC SIGNAL ENVIRONMENT
3600
UNCERTAINTY AREA
HEXAGON
3691
ELECTROMAGNETIC SIGNAL SOURCE
3604
MAXIMUM
3623
LOCATION
3622
NEXT LOCATION
3624
CURRENT LOCATION
3625
SUBSEQUENT NEIGHBOR LOCATION
3645
NEAREST NEIGHBOR
3644
NEIGHBOR LOCATION
3643
3681
ELECTROMAGNETIC SIGNALS
3603
3601
ELECTROMAGNETIC SIGNAL RECEIVER SYSTEM
ELECTROMAGNETIC SIGNAL RECEIVER
3602
FIELD OF VIEW
3621
TELESCOPE
3682
RECEIVER
3683
COMPUTER SYSTEM
3612
THRESHOLD
3647
TIME
3648
SCAN PARAMETERS
3670
OVERLAP
3671
BEAM DIVERGENCE
3672
DWELL TIME
3673
CONTROLLER
3614
PROCESSOR UNITS
3616
PROGRAM INSTRUCTIONS
3618
NEAREST TO MAXIMUM SCAN
3640
NEAREST TO MAXIMUM HEXAGONAL SCAN
3641
NEAREST NEIGHBOR SCAN
3642
HYBRID SCAN
3663

FIG. 36

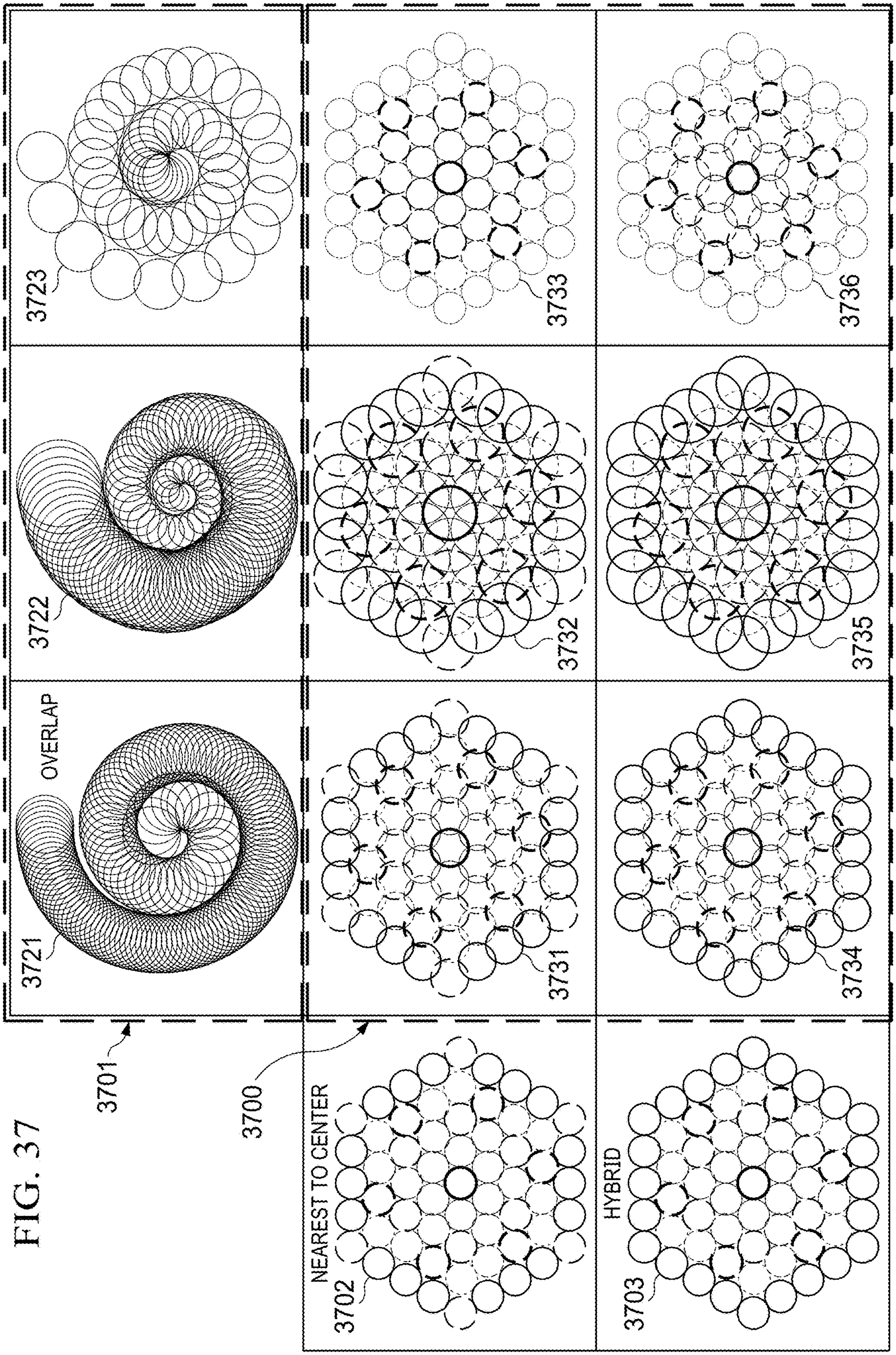

3701
3700
3721
OVERLAP
3722
3723
3731
3732
3733
3734
3735
3736
NEAREST TO CENTER
3702
HYBRID
3703

FIG. 37

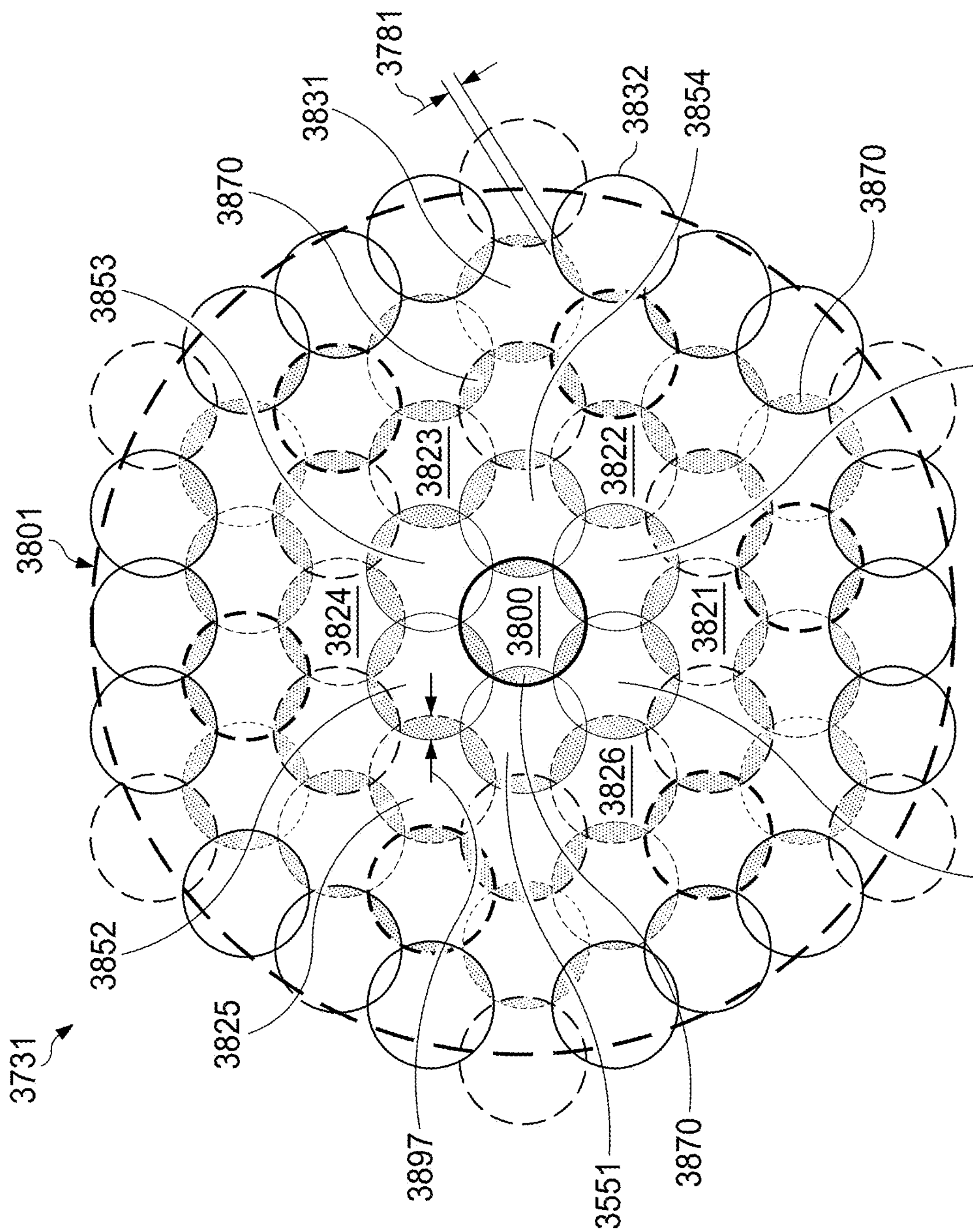

3781
3831
3832
3854
3870
3870
3853
3855
3823
3822
3801
3824
3800
3821
3826
3856
3852
3825
3731
3897
3551
3870

FIG. 38

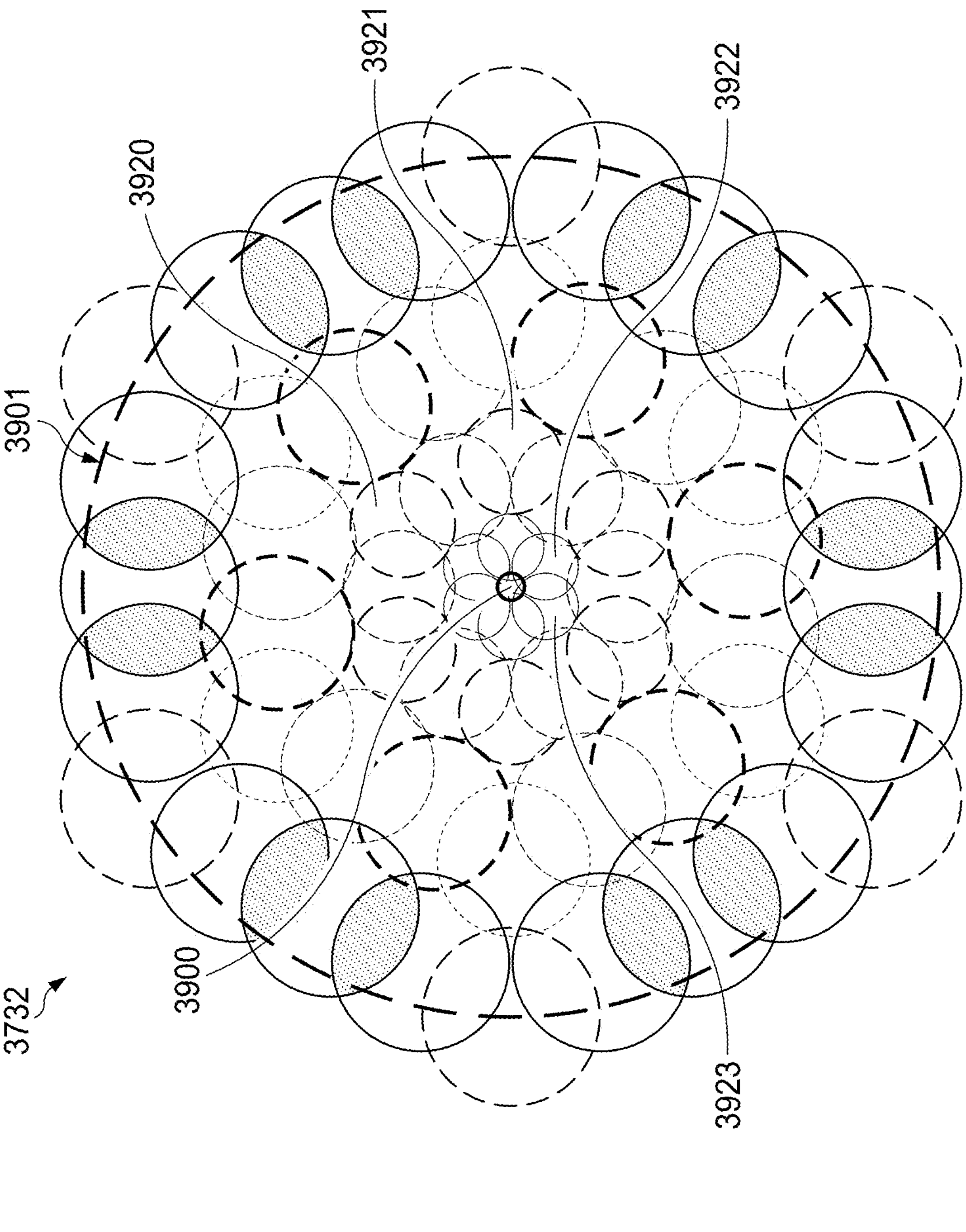


FIG. 39

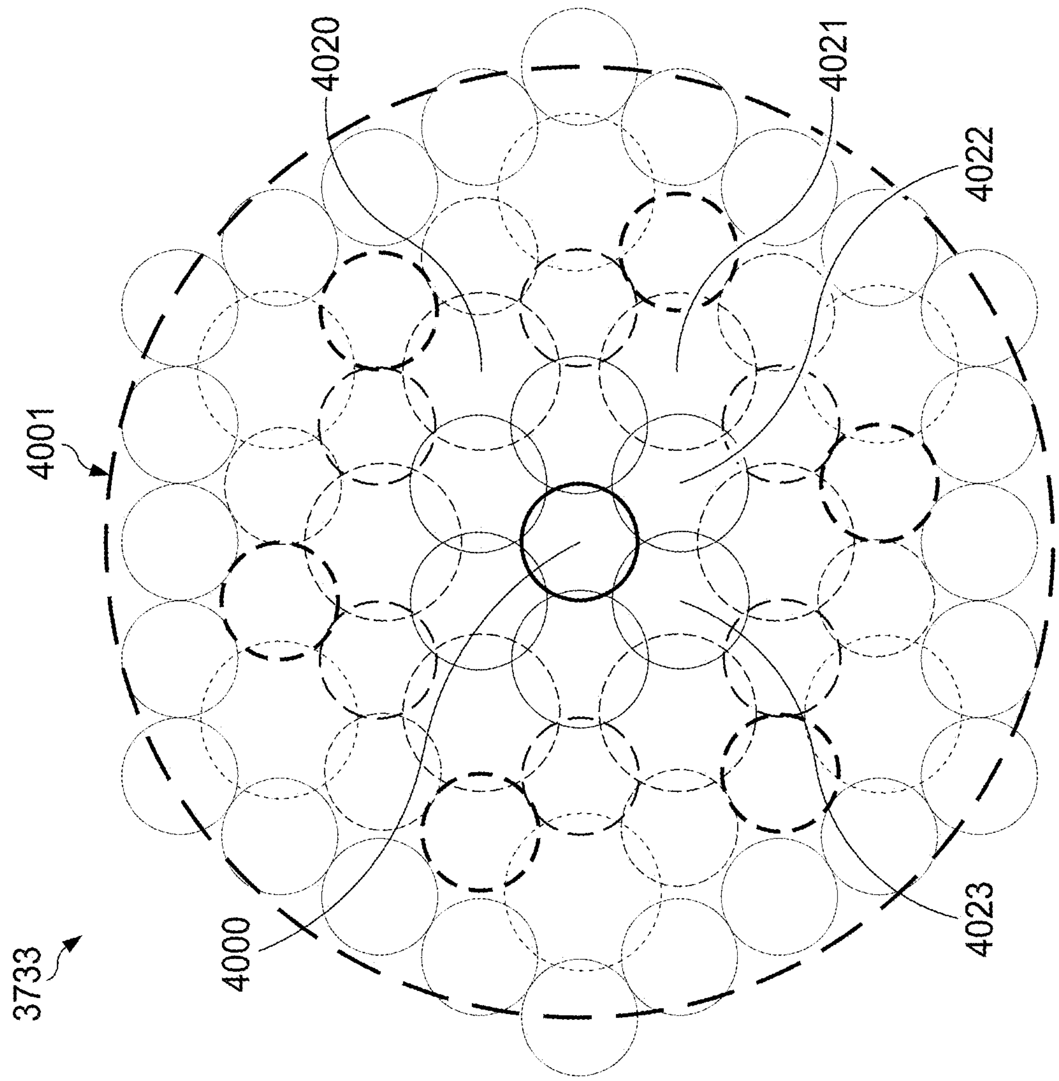


FIG. 40

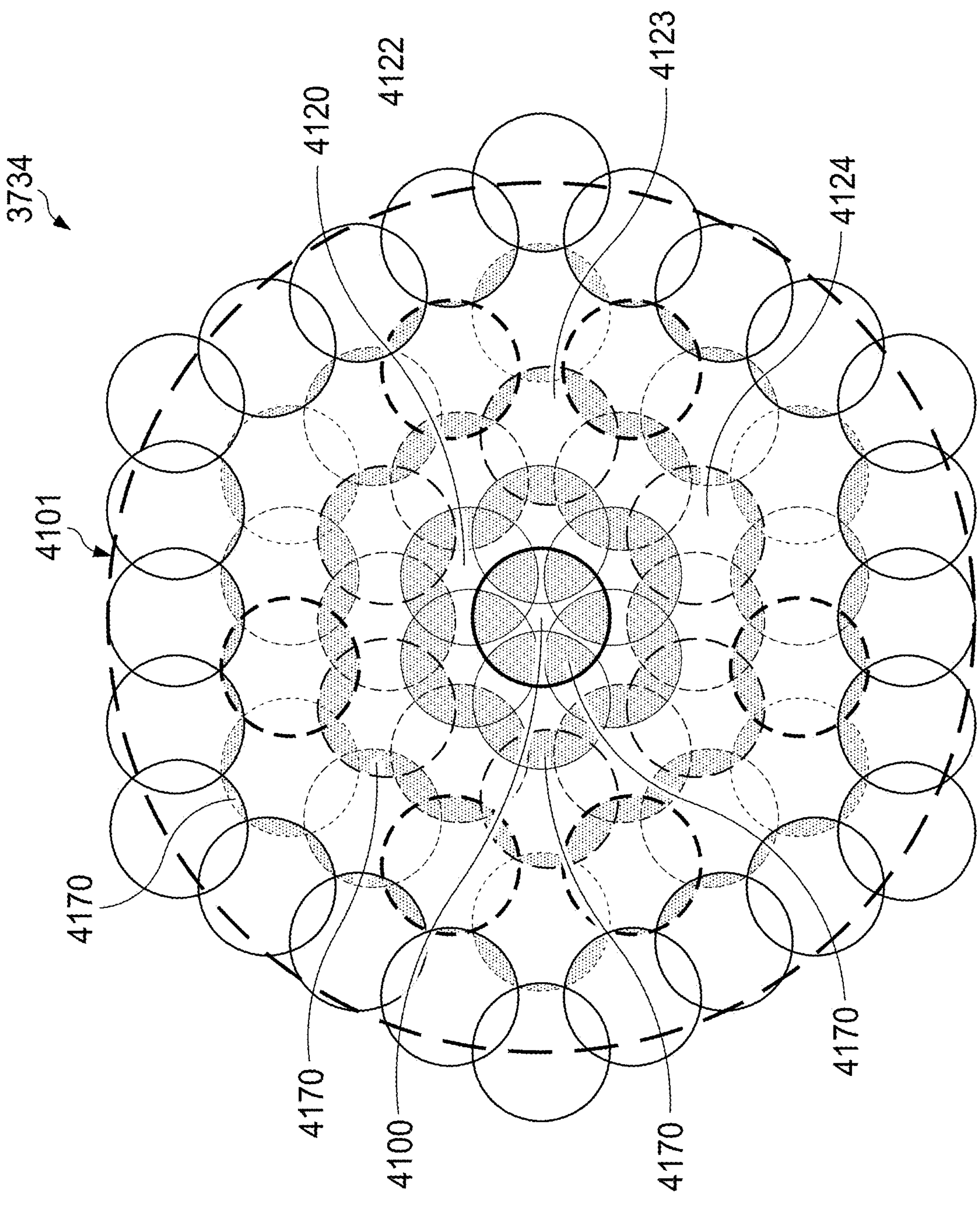


FIG. 41

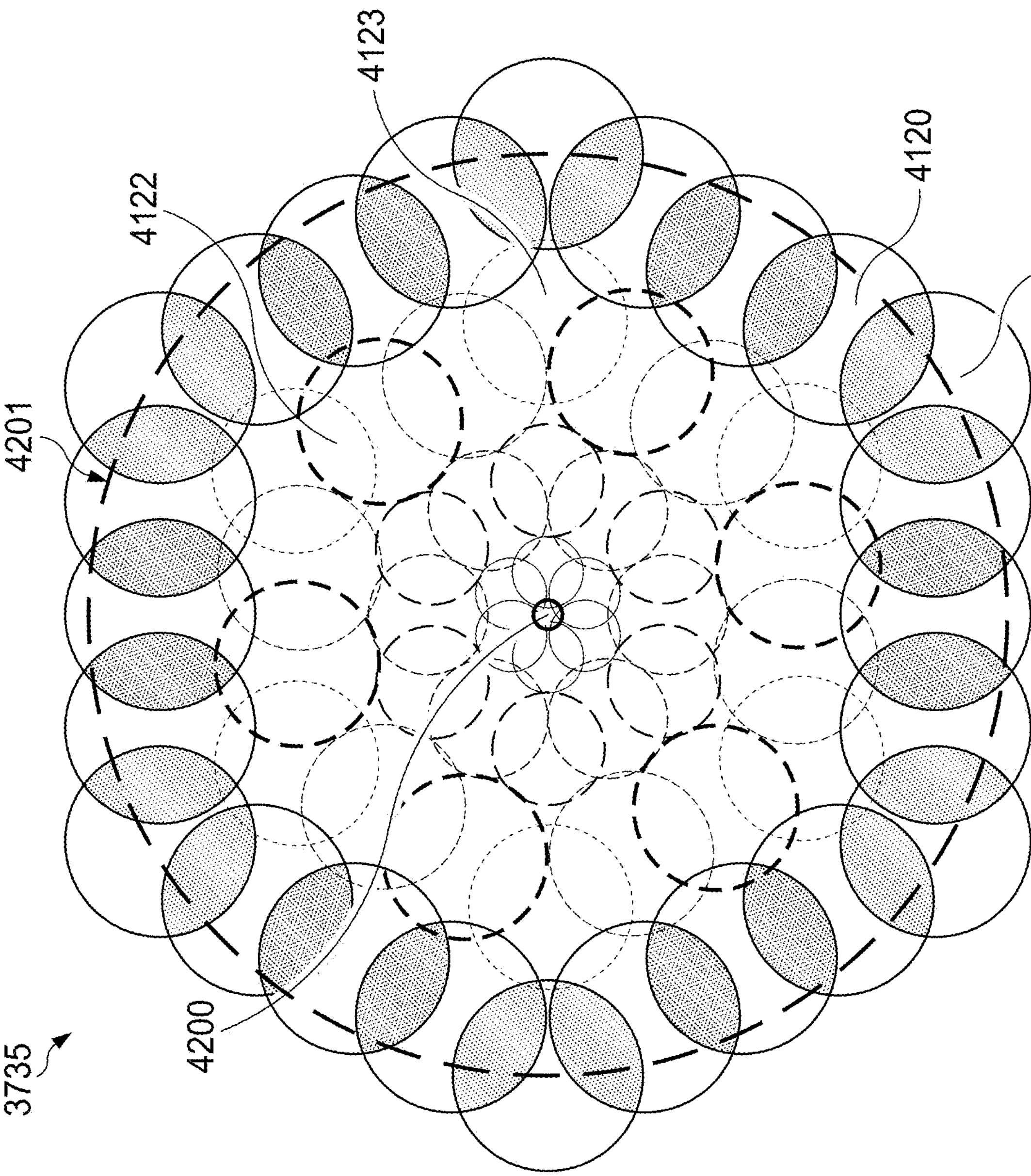


FIG. 42

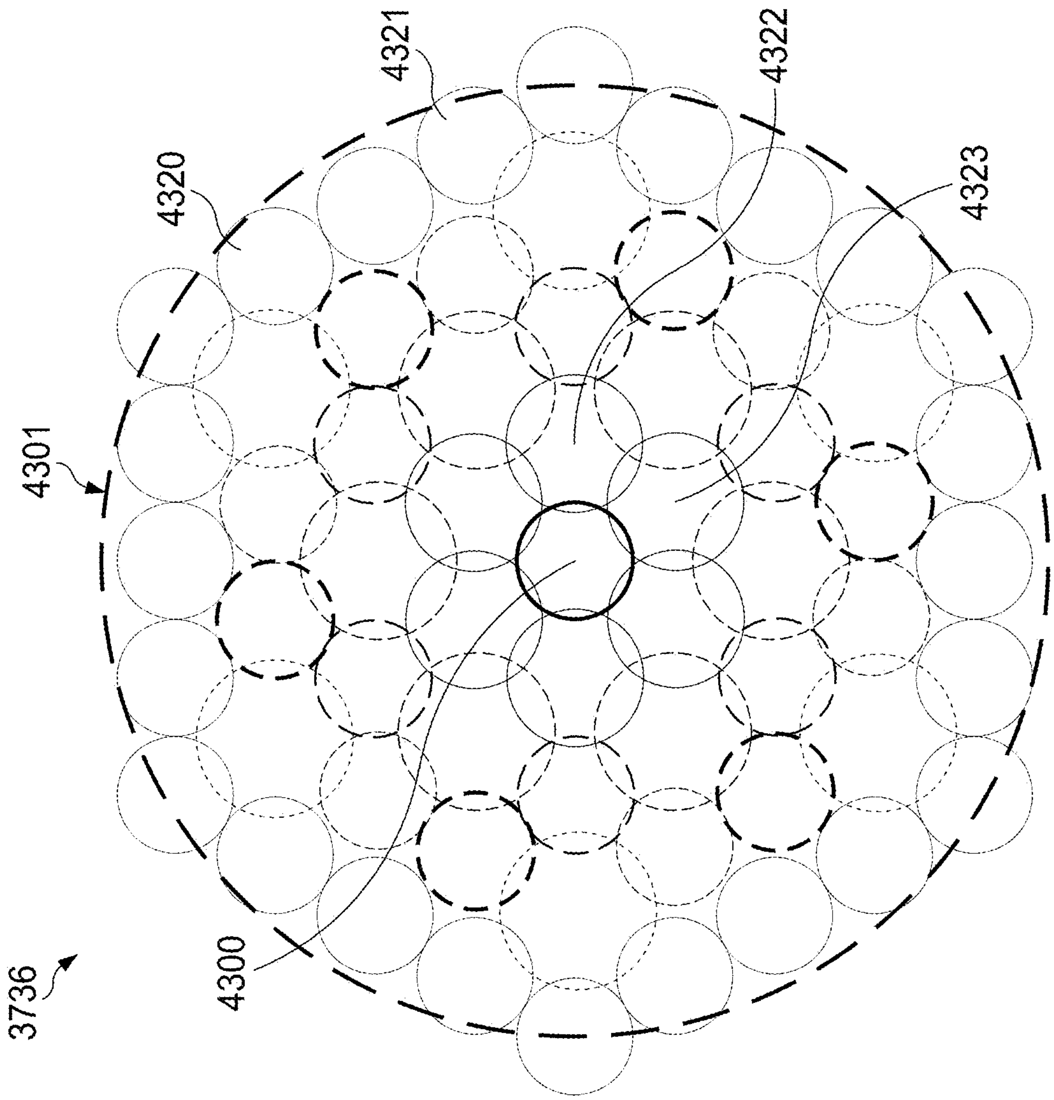


FIG. 43

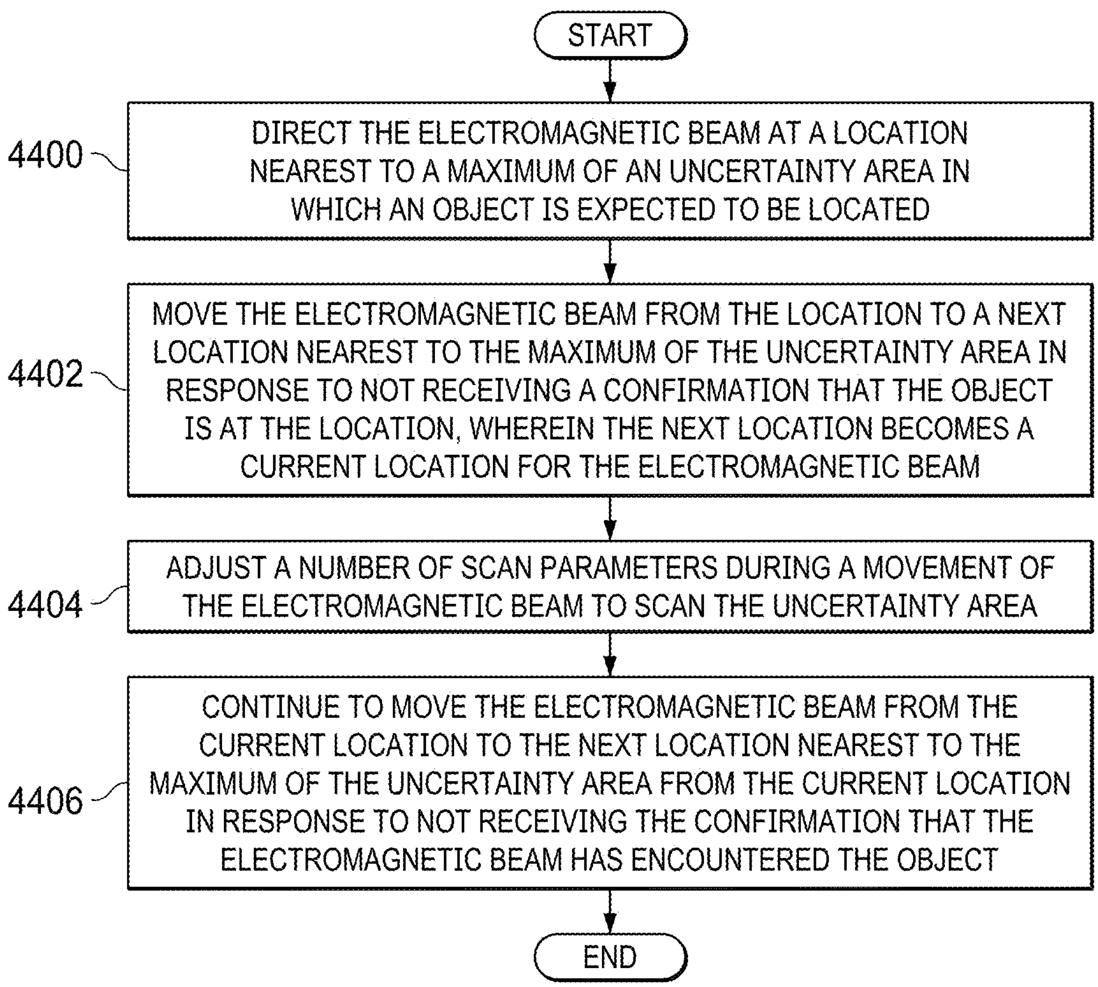

START
4400
DIRECT THE ELECTROMAGNETIC BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH AN OBJECT IS EXPECTED TO BE LOCATED
4402
MOVE THE ELECTROMAGNETIC BEAM FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE OBJECT IS AT THE LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE ELECTROMAGNETIC BEAM
4404
ADJUST A NUMBER OF SCAN PARAMETERS DURING A MOVEMENT OF THE ELECTROMAGNETIC BEAM TO SCAN THE UNCERTAINTY AREA
4406
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
END

FIG. 44

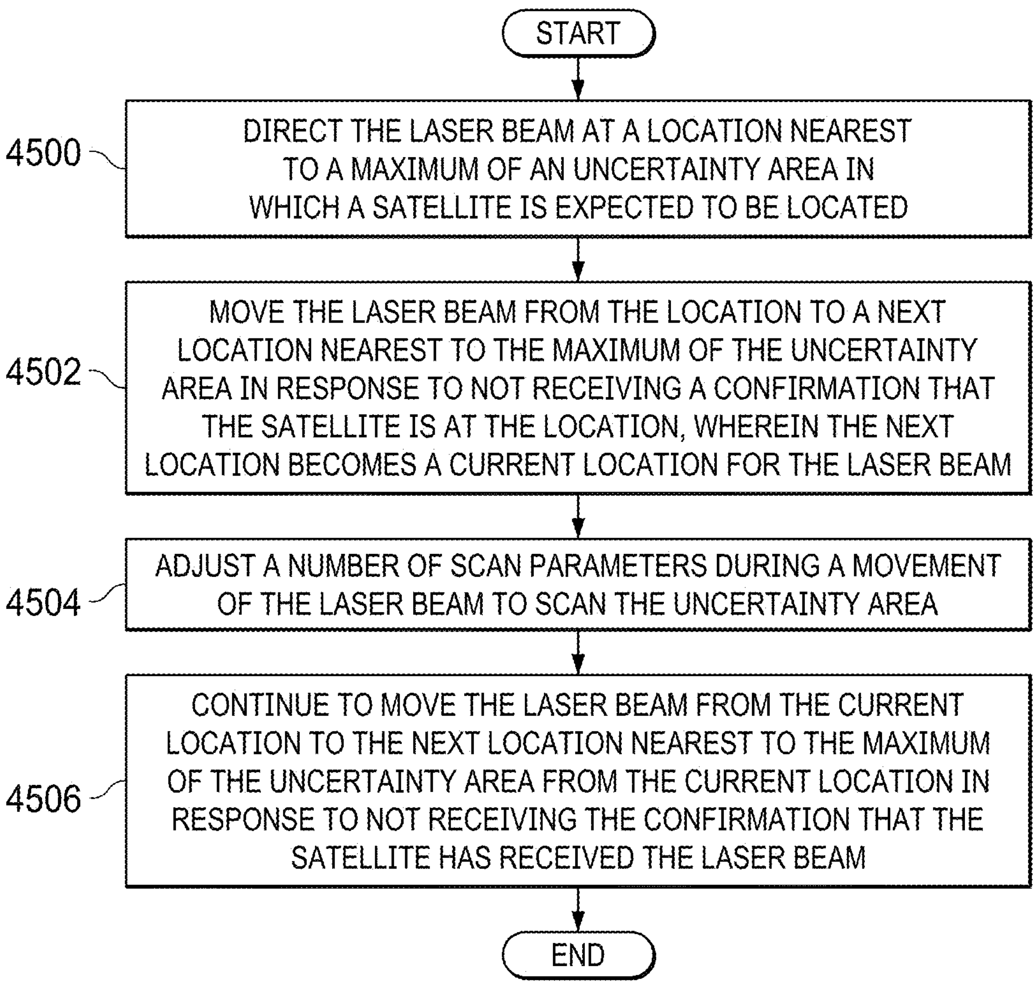

START
4500
DIRECT THE LASER BEAM AT A LOCATION NEAREST TO A MAXIMUM OF AN UNCERTAINTY AREA IN WHICH A SATELLITE IS EXPECTED TO BE LOCATED
4502
MOVE THE LASER BEAM FROM THE LOCATION TO A NEXT LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA IN RESPONSE TO NOT RECEIVING A CONFIRMATION THAT THE SATELLITE IS AT THE LOCATION, WHEREIN THE NEXT LOCATION BECOMES A CURRENT LOCATION FOR THE LASER BEAM
4504
ADJUST A NUMBER OF SCAN PARAMETERS DURING A MOVEMENT OF THE LASER BEAM TO SCAN THE UNCERTAINTY AREA
4506
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
END

FIG. 45

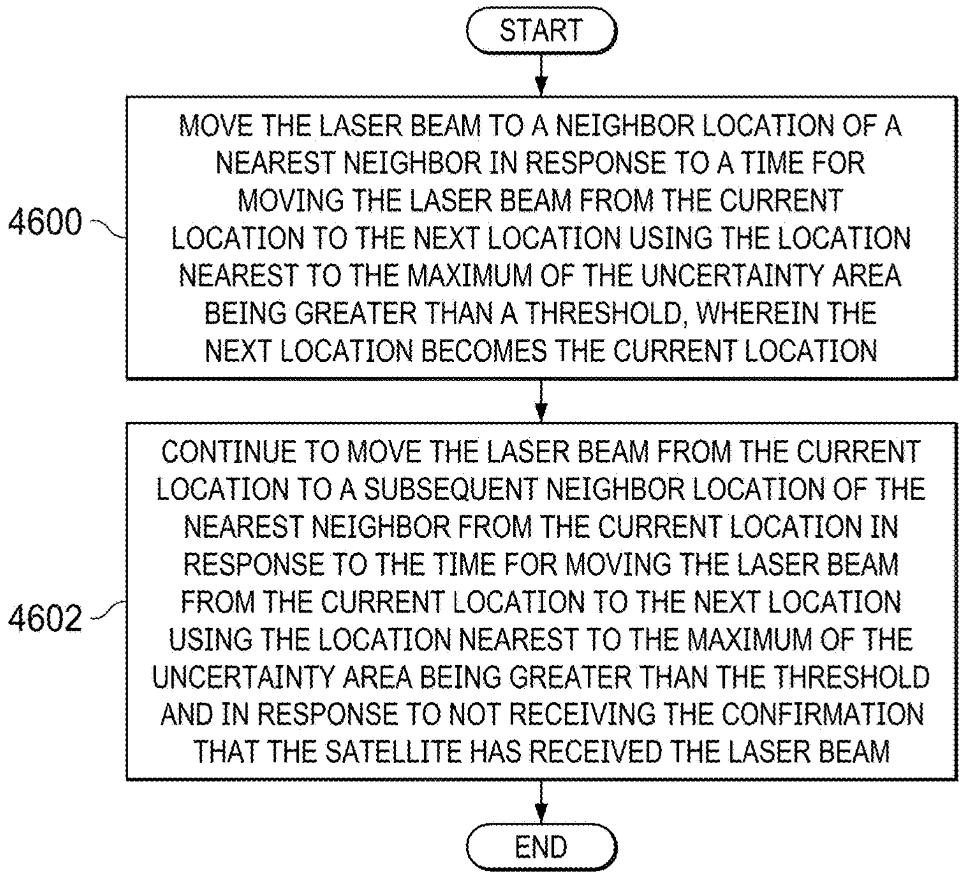

START
MOVE THE LASER BEAM TO A NEIGHBOR LOCATION OF A NEAREST NEIGHBOR IN RESPONSE TO A TIME FOR MOVING THE LASER BEAM FROM THE CURRENT LOCATION TO THE NEXT LOCATION USING THE LOCATION NEAREST TO THE MAXIMUM OF THE UNCERTAINTY AREA BEING GREATER THAN A THRESHOLD, WHEREIN THE NEXT LOCATION BECOMES THE CURRENT LOCATION
4600
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
4602
END

FIG. 46

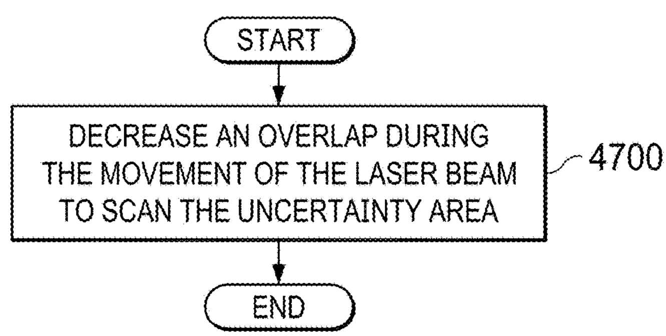

START
DECREASE AN OVERLAP DURING THE MOVEMENT OF THE LASER BEAM TO SCAN THE UNCERTAINTY AREA
4700
END

FIG. 47

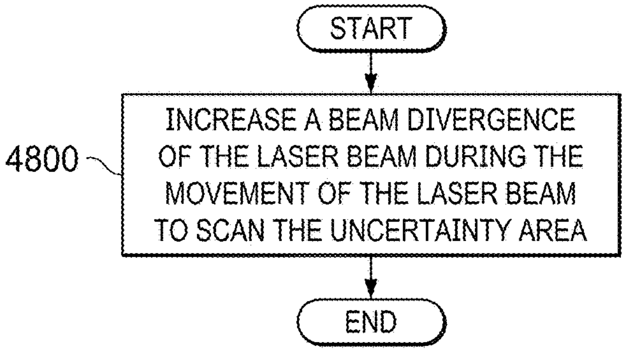


FIG. 48

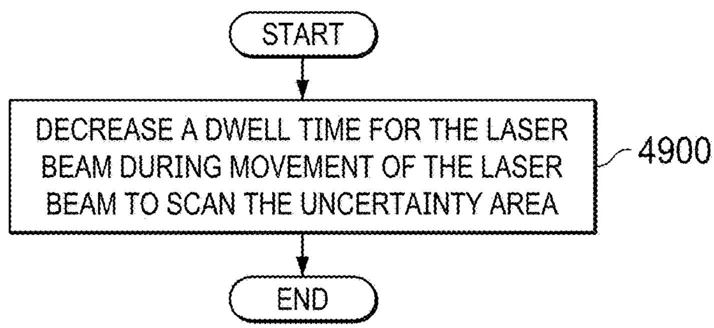


FIG. 49

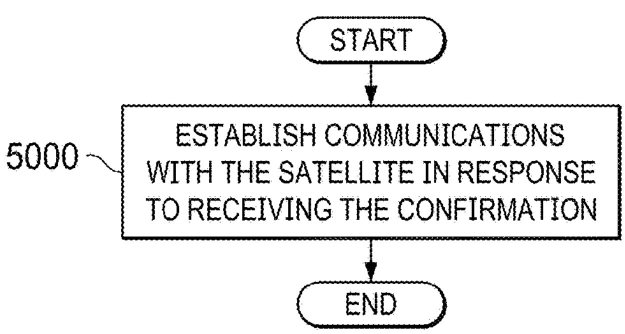


FIG. 50

NONLINEAR LASER BEAM SCAN PATTERN

CROSS-REFERENCE TO RELATED APPLICATION

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

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

STATEMENT OF GOVERNMENT SUPPORT

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

BACKGROUND INFORMATION

1. Field

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

2. Background

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

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

SUMMARY

[0007] An example of the present disclosure provides a laser beam transmission system comprising a laser beam system and a controller. The laser beam system is configured to transmit a laser beam. The controller is configured to control the laser beam system to direct the laser beam at a 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 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 system to adjust a number of scan parameters during a movement of the laser beam to scan the uncertainty area. The controller is configured to control the laser beam system to continue to move the laser beam from the current location to the next location 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.

[0008] Another example of the present disclosure provides an electromagnetic beam transmission system comprising an electromagnetic beam system and a controller. The electromagnetic beam system is configured to transmit an electromagnetic beam. The controller is configured to control the electromagnetic beam 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 and 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 adjust a number of scan parameters during a movement of the electromagnetic beam to scan the uncertainty area. 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.

[0009] Yet 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 number of scan parameters is adjusted during a movement of the laser beam to scan the uncertainty area. The laser beam 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 receiving the confirmation that the satellite has received the laser beam.

[0010] Still another example of the present disclosure provides a method for pointing an electromagnetic beam. The electromagnetic beam is pointed 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, wherein the next location becomes a current location for the electromagnetic beam. The number of scan parameters is adjusted during a movement of the electromagnetic beam to scan the uncertainty area. The electromagnetic beam 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 receiving the confirmation that the electromagnetic beam has encountered the object.

[0011] Another example of the present disclosure provides an electromagnetic signal receiver system comprising an electromagnetic signal receiver and a controller. The electromagnetic signal receiver is configured to receive electromagnetic signals. The controller is configured to control the electromagnetic signal receiver to move a field of view of the electromagnetic signal receiver to a location nearest to a maximum of an uncertainty area in which an electromagnetic signal source is expected to be located and 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 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 adjust a number of scan parameters during a movement of the field of view to scan the uncertainty area. The controller is configured to control the electromagnetic signal receiver to continue to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not detecting electromagnetic signals from the electromagnetic signal source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

[0013] FIG. **1** is a pictorial illustration of a satellite communications environment in which illustrative examples may be implemented;

[0014] FIG. **2** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0015] FIG. **3** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative example;

[0016] FIG. **4** is an illustration of locations for pointing an electromagnetic beam system or an electromagnetic signal receiver in accordance with an illustrative example;

[0017] FIG. **5** is an illustration of locations and beam spots and angles between beam spots in accordance with an illustrative example;

[0018] 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;

[0019] FIG. **7** is an illustration of a flowchart of a method for pointing an electromagnetic beam in accordance with an illustrative example;

[0020] FIG. **8** is an illustration of a flowchart of a method for pointing a laser beam in accordance with an illustrative example;

[0021] FIG. **9** is an illustration of a flowchart of a process for continuing to move a laser beam in accordance with an illustrative example;

[0022] FIG. **10** is an illustration of a flowchart of a process for continuing a laser beam in accordance with an illustrative example;

[0023] FIG. **11** is an illustration of a flowchart of a process for moving a laser beam in accordance with an illustrative example;

[0024] FIG. **12** is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0025] FIG. **13** is an illustration of a flowchart of a process for receiving electromagnetic signals in accordance with an illustrative example;

[0026] 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;

[0027] 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;

[0028] FIG. **16** is an illustration of a flowchart of an operation for moving a field of view in accordance with an illustrative example;

[0029] FIG. **17** is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative example;

[0030] FIG. **18** is an illustration of a flowchart of a process for detecting electromagnetic signals in accordance with an illustrative example;

[0031] FIG. **19** is an illustration of a block diagram of a data processing system in accordance with an illustrative example;

[0032] FIG. **20** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0033] FIG. **21** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0034] FIG. **22** is an illustration of hexagonal scans performed using scan parameters that are adjusted during the scanning of a search area in accordance with an illustrative embodiment;

[0035] FIG. **23** is an illustration of a hexagon scan with decreasing overlap in accordance with an illustrative embodiment;

[0036] FIG. **24** is an illustration of a hexagon scan with increasing beam divergence in accordance with an illustrative embodiment;

[0037] FIG. **25** is an illustration of a hexagon scan with decreasing dwell time in accordance with an illustrative embodiment;

[0038] FIG. **26** is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;

[0039] FIG. **27** is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;

[0040] FIG. **28** is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0041] FIG. **29** is an illustration of a flowchart of a process for decreasing overlap in accordance with an illustrative embodiment;

[0042] FIG. **30** is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0043] FIG. **31** is an illustration of a flowchart of a process for increasing beam divergence in accordance with an illustrative embodiment;

[0044] FIG. **32** is an illustration of a flowchart of a process for adjusting a number of scan parameters in accordance with an illustrative embodiment;

[0045] FIG. **33** is an illustration of a flowchart of a process for decreasing dwell time in accordance with an illustrative embodiment;

[0046] FIG. **34** is an illustration of a flowchart of a process for receiving electromagnetic signals in accordance with an illustrative embodiment;

[0047] FIG. **35** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0048] FIG. **36** is an illustration of a block diagram of an electromagnetic signal environment in accordance with an illustrative embodiment;

[0049] FIG. **37** is an illustration of scans performed using scan parameters that are adjusted during the scanning of an uncertainty area in accordance with an illustrative embodiment;

[0050] FIG. **38** is an illustration of a nearest to center scan with decreasing overlap in accordance with an illustrative embodiment;

[0051] FIG. **39** is an illustration of a nearest to center scan with increasing beam divergence in accordance with an illustrative embodiment;

[0052] FIG. **40** is an illustration of a nearest to center scan with decreasing dwell time in accordance with an illustrative embodiment;

[0053] FIG. **41** is an illustration of a hybrid scan with decreasing overlap in accordance with an illustrative embodiment;

[0054] FIG. **42** is an illustration of a hybrid scan with increasing beam divergence in accordance with an illustrative embodiment;

[0055] FIG. **43** is an illustration of a hybrid scan with decreasing dwell time in accordance with an illustrative embodiment;

[0056] FIG. **44** is an illustration of a flowchart of a process for pointing an electromagnetic beam in accordance with an illustrative embodiment;

[0057] FIG. **45** is an illustration of a flowchart of a process for pointing a laser beam in accordance with an illustrative embodiment;

[0058] FIG. **46** is an illustration of a flowchart of a process for moving the laser beam in accordance with an illustrative embodiment;

[0059] FIG. **47** is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment;

[0060] FIG. **48** is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment;

[0061] FIG. **49** is an illustration of a flowchart of a process for adjusting scan parameters in accordance with an illustrative embodiment; and

[0062] FIG. **50** is an illustration of a flowchart of a process for establishing communications in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] 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**.

[0071] 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.

[0072] 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.

[0073] 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**.

[0074] 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.

[0075] 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.

[0076] 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**.

[0077] 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.

[0078] In this illustrative example, satellite **120** is expected to be within area **134**.

[0079] 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**.

[0080] 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**.

[0081] 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**.

[0082] 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.

[0083] 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.

[0084] 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.

[0085] 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.

[0086] 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**.

[0087] 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.

[0088] 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**.

[0089] 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.

[0090] 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**.

[0091] Electromagnetic beam system **220** is a physical hardware system. This hardware system is configured to transmit electromagnetic beam **203**.

[0092] 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**.

[0093] 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.

[0094] 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.

[0095] 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.

[0096] 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.

[0097] 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.

[0098] 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.

[0099] 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**.

[0100] 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.

[0101] 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**.

[0102] 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.

[0103] 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**.

[0104] 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.

[0105] 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.

[0106] 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.

[0107] 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.

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

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

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

[0111] In this example, controller **214** controls electromagnetic beam system **220** to move electromagnetic beam **203** from location **222** to next location **224** nearest to maximum **223** of uncertainty area **281** in response to not receiving confirmation **227** that object **293** such as electromagnetic beam receiver **204** is at location **222**. In this example, next location **224** becomes current location **225** for electromagnetic beam **203**.

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

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

[0114] 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**.

[0115] 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.

[0116] 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**.

[0117] 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**.

[0118] 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**.

[0119] 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**.

[0120] 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.

[0121] 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.

[0122] 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.

[0123] 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.

[0124] 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**.

[0125] 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**.

[0126] 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.

[0127] 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.

[0128] 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.

[0129] 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**.

[0130] 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**.

[0131] 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.

[0132] 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.

[0133] 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.

[0134] 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**.

[0135] 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.

[0136] 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**.

[0137] 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**.

[0138] 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:

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

[0139] where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{rot} is a total time $t_{rot}=t_{slew}+t_{dwell}$, 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.

[0140] 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**.

[0141] 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.

[0142] 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.

[0143] 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.

[0144] 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.

[0145] 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**.

[0146] 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**.

[0147] 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).

[0148] 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.

[0149] 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.

[0150] 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.

[0151] 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**.

[0152] 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**.

[0153] 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**.

[0154] 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**.

[0155] 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.

[0156] 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.

[0157] 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**.

[0158] 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**.

[0159] 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**.

[0160] 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.

[0161] 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.

[0162] 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**.

[0163] 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.

[0164] 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.

[0165] 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.

[0166] 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**.

[0167] 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**.

[0168] 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:

$$M = PDF_{in}t / t_{tot}$$

where PDF_{int} is a probability density function integrated over an area of interest for a next potential location and t_{rot} 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.

[0169] 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.

[0170] 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**.

[0171] For example, the first location can be locations for center **402**. The next locations closest to center **402** are locations A.

[0172] 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.

[0173] 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.

[0174] 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.

[0175] 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.

[0176] In this example, the beam spot pattern can be determined using a nearest to maximum scan. For a given beam spot pattern, the following equation can be used:

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

[0177] 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.

[0178] t_{scan} is the total scan time to use the nearest neighbor scan.

[0179] N is the total number of beam spots in the scan pattern.

[0180] 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".

[0181] 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.

[0182] φ_{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.

[0183] θ_{nn} is the angular separation between two beam spots when jumping from beam spot to beam spot using the nearest neighbor scan.

[0184] 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

[0185] 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:

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

[0186] Since PDF(φ_{cc})cc)≥PDF(φ_{nn}), $t_{net\ savings}$≥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

[0187] In this example, the slew rate can be considered zero resulting in the following:

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

[0188] In this case, the nearest to maximum scan is not needed because the $t_{net\ savings}$<0.

Example 3

[0189] 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.

[0190] 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.

[0191] 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**.

[0192] In this example, the pointing involves moving or directing electromagnetic beam **203** in FIG. **2** or field of view **321** in FIG. **3**.

[0193] 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).

[0194] 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**).

[0195] 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.

[0196] In this example, the total time, t_{rot}, 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.

[0197] 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 Ly 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.

[0198] 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.

[0199] 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**.

[0200] 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**).

[0201] 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.

[0202] 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.

[0203] 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**.

[0204] 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.

[0205] The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving a confirmation that the satellite has received the laser beam (operation **804**). The process terminates thereafter.

[0206] 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**.

[0207] The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a 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.

[0208] 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**.

[0209] 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.

[0210] 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**.

[0211] 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.

[0212] 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.

[0213] 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**.

[0214] 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.

[0215] 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**.

[0216] 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**).

[0217] The process continues to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location 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.

[0218] 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**.

[0219] The process continues to move the field of view from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not detecting the electromagnetic signals from the electromagnetic signal source (operation **1400**). The process terminates thereafter.

[0220] 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**.

[0221] 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.

[0222] 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**.

[0223] 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.

[0224] 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.

[0225] 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**.

[0226] The process establishes communications with the electromagnetic signal source in response to detecting the electromagnetic signals (operation **1700**). The process terminates thereafter.

[0227] 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**.

[0228] The process detects the electromagnetic signals from the electromagnetic signal source in response to detecting selected electromagnetic signals that are greater than a noise level in the field of view (operation **1800**). The process terminates thereafter. In operation **1800**, the communications are selected from one of unidirectional communications and bidirectional communications.

[0229] The flowcharts and block diagrams in the different depicted examples in FIGS. **6-18** illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative example. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0230] 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.

[0231] 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**.

[0232] 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.

[0233] 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.

[0234] 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.

[0235] 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**.

[0236] 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.

[0237] 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.

[0238] 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**.

[0239] 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**.

[0240] 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**.

[0241] Computer-readable storage media **1924** is a physical or tangible storage device used to store program instructions **1918** rather than a medium that propagates or transmits program instructions **1918**. Computer-readable storage media **1924** may be at least one of an electronic storage medium, a magnetic storage medium, an optical storage medium, an electromagnetic storage medium, a semiconductor storage medium, a mechanical storage medium, or other physical storage medium. Some known types of storage devices that include these mediums include: a diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device, such as punch cards or pits/lands formed in a major surface of a disc, or any suitable combination thereof.

[0242] 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.

[0243] 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.

[0244] 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.

[0245] 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.

[0246] 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**.

[0247] 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

[0248] A laser beam transmission system comprising:

[0249] a laser beam system configured to transmit a laser beam;

[0250] a controller configured to control the laser beam system to:

[0251] direct the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

[0252] 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

[0253] 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

[0254] 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

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

[0256] continue to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location with a dwell time at each location in response to not receiving the confirmation that the satellite has received the laser beam.

Clause 4

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

[0258] 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

[0259] The laser beam transmission system of clause 1, wherein the controller is configured to control the laser beam system to:

[0260] 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

[0261] 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

[0262] 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

[0263] The laser beam transmission system of clause 1, wherein the controller is configured to:

[0264] establish communications with the satellite in response to receiving the confirmation.

Clause 8

[0265] The laser beam transmission system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0266] 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

[0267] An electromagnetic beam transmission system comprising: an electromagnetic beam system configured to transmit an

[0268] electromagnetic beam;

[0269] a controller configured to control the electromagnetic beam transmission system to:

[0270] direct the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0271] 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

[0272] 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

[0273] 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.

[0274] Clause 12. An electromagnetic beam transmission system comprising:

[0275] an electromagnetic beam system configured to transmit an electromagnetic beam;

[0276] a controller configured to control the electromagnetic beam transmission system to:

[0277] 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;

[0278] 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

[0279] 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

[0280] 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:

$$M=PDF\mathrm{int}/\mathrm{ttot}$$

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

Clause 14

[0281] A method for pointing a laser beam, the method comprising:

[0282] directing the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located;

[0283] 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

[0284] 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

[0285] 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

[0286] The method of clause 14, wherein continuing to move the laser beam comprises:

[0287] 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

[0288] The method of clause 14, wherein continuing to move the laser beam comprises:

[0289] 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

[0290] The method of clause 14 further comprising:

[0291] 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

[0292] 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

[0293] 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

[0294] The method of clause 14 further comprising:

[0295] establishing communications with the satellite in response to receiving the confirmation.

Clause 21

[0296] The method of clause 20, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0297] 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

[0298] A method for pointing an electromagnetic beam, the method comprising:

[0299] directing the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located;

[0300] 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

[0301] 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.

[0302] 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.

[0303] 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.

[0304] 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.

[0305] 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

[0306] An electromagnetic signal receiver system comprising:

- **[0307]** an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;
- **[0308]** a controller configured to control the electromagnetic signal receiver to:
  - **[0309]** 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;
  - **[0310]** 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
- **[0311]** 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

[0312] 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.

[0313] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0314] 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

[0315] The electromagnetic signal receiver system of clause 1, wherein in continuing to move the field of view, the controller is configured to:

[0316] 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

[0317] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to control the electromagnetic signal receiver system to:

- **[0318]** 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
- **[0319]** 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

[0320] 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

[0321] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:

[0322] establish communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 8

[0323] The electromagnetic signal receiver system of clause 7, wherein the communications are selected from one of unidirectional communications and bidirectional communications.

Clause 9

[0324] The electromagnetic signal receiver system of clause 1, wherein the controller is configured to:
[0325] 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

[0326] The electromagnetic signal receiver system of clause 1, wherein the electromagnetic signal receiver is selected from a group comprising a telescope.

Clause 11

[0327] 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

[0328] An electromagnetic signal receiver system comprising:
- **[0329]** an electromagnetic signal receiver having a field of view in which electromagnetic signals are received;
- **[0330]** a controller configured to control the electromagnetic signal receiver to:
  - **[0331]** 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;
  - **[0332]** 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
- **[0333]** 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

[0334] 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:

$$M = PDFint / ttot$$

[0335] 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

[0336] A method for receiving electromagnetic signals comprising:
- **[0337]** 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;
- **[0338]** 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
- **[0339]** 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

[0340] 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

[0341] The method of clause 14, wherein continuing to move the field of view comprises:
[0342] 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.
[0343] 17. The method of claim **14**, continuing to move the field of view comprises:
[0344] 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

[0345] The method of clause 14 further comprising:
- **[0346]** 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
- **[0347]** 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

[0348] 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

[0349] The method of clause 14 further comprising:

[0350] establishing communications with the electromagnetic signal source in response to detecting the electromagnetic signals.

Clause 21

[0351] The method of clause 20 wherein the communications is selected from one of unidirectional communications and bidirectional communications.

Clause 22

[0352] The method of clause 14 further comprising:

[0353] 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

[0354] 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.

[0355] The illustrative embodiments recognize and take into account one or more different considerations as described herein. During the initial acquisition in establishing the communications link, a time efficient scanning method for pointing laser beams at satellites is desired. Various scanning methods can be used to point a laser beam from a transmitting satellite to a receiving satellite. In satellite communications, lasers beams can have different wavelengths such as, for example, a wavelength of about 1064 nm in the near infrared wavelength range, 1550 nm in the visible wavelength range, and 532 nm in the visible wavelength range.

[0356] With the distances separating satellites, establishing communications between the satellites using laser beams requires a time efficient scanning technique. The speed at which an area to be scanned to locate a satellite is important in establishing the communications link as quickly as possible. For example, a service-level agreement (SLA) may require establishing a communications link within a specified amount of time.

[0357] Using the most time efficient technique for scanning an area to locate a satellite is important in quickly establishing communications links between satellites using laser beams to meet service-level agreements (SLAs) and other requirements or agreements.

[0358] Current laser scanning methods include a continuous spiral scan, a step spiral scan, a segment scan, and a raster scan. These types of scans for establishing the communications link may not be sufficiently fast to establish communications as quickly as needed to meet various requirements that may be present.

[0359] Currently, the different parameters for scanning for a satellite are fixed during the entire scan. However, given the probability of finding a satellite typically changes from location to location, the scan parameters can be changed from location to location to efficiently search for the satellite. In some cases, the scan parameters can be changed between some locations and not all of the locations.

[0360] With reference now to FIG. **20**, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment **2000** includes components that can be implemented in hardware such as the hardware in satellite **101** and satellite **102** in FIG. **1**. In this example, electromagnetic beam transmission system **2002** is an example of an implementation of electromagnetic beam transmission system **202** in FIG. **2**. The components can be implemented using components in electromagnetic beam transmission system **2002** in electromagnetic beam transmission system **202** in FIG. **2**.

[0361] In this illustrative example, electromagnetic beam transmission system **2002** can point the transmission of electromagnetic beam **2003** at object **2093**. In this example, object **2093** can be electromagnetic beam receiver **2004**. Electromagnetic beam receiver **2004** can be connected to object **2093** in this example. For example, object **2093** can be satellite **2038**.

[0362] In this illustrative example, electromagnetic beam transmission system **2002** comprises electromagnetic beam system **2020** and controller **2014**. In this example, controller **214** is located in computer system **2012**. As depicted, computer system **2012** is also part of electromagnetic beam transmission system **2002**.

[0363] Electromagnetic beam system **2020** is a physical hardware system. This hardware system is configured to transmit electromagnetic beam **2003**.

[0364] Controller **2014** can be implemented in a similar manner as controller **214** in FIG. **2** in which program instructions **2018** can be used to implement controller **2014** that are executed by a number of processor units **2016** in computer system **2012**. In this example, controller **2014** includes processes similar to those in controller **214** in FIG. **2** but also includes additional processes for controlling the manner in which a scan is performed. Program instructions **2018**, the number of processor units **2016**, and computer system **2012** can be implemented in a similar manner to program instructions **218**, processor units **216**, and computer system **212** in FIG. **2**.

[0365] In this illustrative example, controller **2014** controls electromagnetic beam transmission system **2002** to direct electromagnetic beam **2003** at location **2022** in search area **2081** in which object **2093** is expected to be located. In other words, search area **2081** is an area in which object **2093** is believed to be present. This search area **2081** can have a number of different shapes selected from a group comprising a hexagon, a circle, an octagon, an ellipse, or some other shape. Object **2093** may not actually be in search area **2081**. In some cases, search area **2081** can be selected as an area for searching with the intent of locating object **2093**.

[0366] As depicted, electromagnetic beam **2003** has beam spot **2061**. In this example, beam spot **2061** is a diameter of electromagnetic beam **2003** at a location in search area **2081**. In this example, beam spots can correspond to locations in search area **2081**. For example, location **2022** in search area **2081** can have a size and shape that corresponds to the size and shape of beam spot **2061** when the electromagnetic beam **2003** is directed at location **2022**.

[0367] In one illustrative example, electromagnetic beam receiver **2004** is connected to object **2093**. When one component is "connected" to another component, the connection is a physical connection. For example, a first component, electromagnetic beam receiver **2004**, can be considered to be physically connected to a second component, object **2093**, by at least one of being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, or connected to the second component in some other suitable manner. The first component also can be connected to the second component using a third component. The first component can also be considered to be physically connected to the second component by being formed as part of the second component, an extension of the second component, or both. In some examples, the first component can be physically connected to the second component by being located within the second component.

[0368] In this example, controller **2014** controls electromagnetic beam system **2020** to direct electromagnetic beam **2003** at central location **2023** in search area **2081** in which object **2093** is expected to be located. In one example, object **2093** is satellite **2038**. Central location **2023** is the first location for performing hexagonal scan **2040** and is at the center of search area **2081**. Hexagonal scan **2040** occurs with the movement of electromagnetic beam **2003** to scan search area **2081**. In this example, hexagonal scan **2040** has a shape of a hexagon. This type of search can be used with search area **2081** in the form of a hexagon, a circle, an octagon or some other shape that has radial symmetry. For example, if search area **2081** has the shape of a circle, this circle falls within the area scanned by hexagonal scan **2040**. Locations that fall outside of search area **2081** when using hexagonal scan **2040** can be skipped.

[0369] In this example, controller **2014** controls electromagnetic beam system **220** to move electromagnetic beam **2003** to next location **2024** that is nearest neighbor **2044** to central location **2023** in response to not receiving confirmation **2027** that object **2093** is at central location **2023**. Next location **2024** becomes current location **2025** for the electromagnetic beam **2003**.

[0370] Further in this example, controller **214** controls electromagnetic beam system **2020** to adjust a number of scan parameters **2070** during a movement of the electromagnetic beam system **2020** to scan search area **2081**. The number of scan parameters **2070** changes during scanning of search area **2081**. In other words, the number of scan parameters **2070** does not remain fixed during the entire scan. In this illustrative example, the number of scan parameters **2070** can be adjusted by controller **2014** controlling electromagnetic beam system **2020**. In this illustrative example, the number of scan parameters **2070** can be adjusted to increase the likelihood that electromagnetic beam **2003** hits object **2093** in search area **2081**.

[0371] In this depicted example, controller **2014** controls electromagnetic beam system **2020** to continue to move electromagnetic beam **2003** from current location **2025** to next location **2024** that is nearest neighbor **2044** to current location **2025** in response to not receiving confirmation **2027** that object **2093** has received electromagnetic beam **2003**.

[0372] This type of movement of electromagnetic beam **2003** is nearest neighbor scan **2042**. In other words, the movement of electromagnetic beam **2003** is from current location **2025** to subsequent location **2045** that is nearest neighbor **2044** to current location **2025**. In this example, each subsequent neighbor location that electromagnetic beam **2003** moves to is adjacent to current location **2025**. Thus, with this type of movement, the scan performed using electromagnetic beam **2003** is both hexagonal scan **2040** and nearest neighbor scan **2042**. This time of scan can also be referred to as a honeycomb-like laser beam scan.

[0373] In this illustrative example, confirmation **227** can take a number of different forms. For example, confirmation **2027** can be a reply or acknowledgment sent in a return electromagnetic beam to electromagnetic beam system **2020**. In this example, electromagnetic beam system **220** can also receive electromagnetic beams. In another illustrative example, confirmation can be sent through another transmission to controller **2014** through another device such as a radiofrequency receiver or other type of receiver.

[0374] In one illustrative example, electromagnetic beam **2003** can take the form of laser beam **2033**. Further, laser beam **2033** can be selected from a group comprising a continuous laser beam and a pulsed laser beam. Electromagnetic beam system **2020** can be laser beam system **2030** and object **2093** can take the form of satellite **238**. In this example, electromagnetic beam transmission system **2002** is laser beam transmission system **2011**.

[0375] In this example, controller **2014** controls laser beam system **2030** to direct laser beam **2033** at central location **2023** in search area **2081** in which satellite **2038** is expected to be located. Controller **2014** also controls laser beam system **2030** to move laser beam **2033** to next location **2024** that is nearest neighbor **2044** to central location **2023** in response to not receiving confirmation **2027** that satellite **2038** is at central location **2023**. In this example, next location **2024** becomes current location **2025** for laser beam **2033**.

[0376] Further, controller **2014** controls laser beam system **2030** to adjust a number of scan parameters **2070** during a movement of laser beam **2033** to scan search area **2081**. As a result, the number of scan parameters **2070** can change during every movement of laser beam **2033** or during one or more movements of laser beam **2033** to scan search area **2081**.

[0377] For example, controller **2014** can change the number of scan parameters **2070** from location to location. The adjustment to the number of scan parameters **2070** is made to efficiently search for satellite **2038**. In some cases, the number of scan parameters **2070** can be changed between some locations and not all of the locations.

[0378] In this illustrative example, the number of scan parameters **2070** can be adjusted to increase the likelihood that laser beam **2033** hits satellite **2038** in search area **2081**. The number of scan parameters **2070** can be selected from at least one of overlap **2071**, beam divergence **2072**, dwell time **2073**, or other suitable scan parameters. In this illustrative example, controller **2014** can adjust the number of scan parameters **2070** during movement of laser beam **2033**.

[0379] In the illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing overlap **2071** during the movement of laser beam **2033** to scan search area **2081**.

[0380] In one illustrative example, search area **2081** comprises locations **2082** around central location **2023** are arranged in concentric layers **2083** in search area **2081**. These layers can also be referred to as rings and in particular as concentric rings. Each layer in concentric layers **2083** is larger or farther away from central location **2023** than a prior layer in concentric layers **2083**. Central location **2023** can be considered a first layer in concentric layers **2083**.

[0381] With these concentric layers of locations **2082**, controller **2014** adjusts the number of scan parameters **2070** by increasing overlap **2071** at each layer in concentric layers **2083** in the search area **2081** during the movement of laser beam **2033** to scan search area **2081**. Overlap **2071** at locations **2082** in a layer is uniform. In other words, overlap **2071** is the same for all locations in a layer.

[0382] In this example, nearest neighbor scan **2042** involves laser beam **2033** moving along a path from central location **2023** that progresses outward to the perimeter of search area **2081**. Increased overlap results in more time being needed to perform nearest neighbor scan **2042**.

[0383] The amount of overlap in different segments of the path for the scan can be selected such that the time needed to scan the entire path of nearest neighbor scan **2042** is the same as if the path used the same amount of overlap for the entire path. In other words, different segments of the path can have different amounts of overlap such that the total overlap present along the path for the segments can be the same as the total overlap for a path in which the amount of overlap is the same along the path for the scan.

[0384] In another illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing a divergence of laser beam **2033** during the movement of the laser beam **2033** to scan search area **2081**. In one illustrative example, in increasing beam divergence **2072**, controller **2014** increases beam divergence **2072** of laser beam **2033** at each layer in concentric layers **2083** in the search area **2081** during the movement of the laser beam to scan search area **2081**. With this example, beam divergence **2072** of the laser beam **2033** at locations **2082** in a layer is uniform.

[0385] A smaller divergence may increase the ability to detect satellite **2038** at a particular location. However, the smaller divergence means that the path for nearest neighbor scan **2042** is longer to cover search area **2081**. As a result, increasing beam divergence **2072** as laser beam **2033** moves farther away from central location **2023** results in that portion of the path needing less time to cover search area **2081**. As a result, the same amount of time is used for the scan as if beam divergence **2072** remained constant along the entire path for nearest neighbor scan **2042**.

[0386] In still another illustrative example, controller **2014** adjusts the number of scan parameters **2070** by increasing dwell time **2073** for laser beam **2033** during the movement of laser beam **2033** to scan search area **2081**. A longer dwell time increases the ability to detect satellite **2038** at a particular location. However, the increased dwell time results in the need for more time to perform nearest neighbor scan **2042**. As a result, decreasing the dwell time as laser beam **2033** moves away from central location **2023** can reduce the scan time for that portion of the path for nearest neighbor scan **2042**.

[0387] Further, in increasing dwell time **2073**, controller **2014** can increase dwell time **2073** for laser beam **2033** at each layer in concentric layers **2083** in search area **2081** during the movement of laser beam **2033** to scan search area **2081**. With this example, dwell time **2073** of laser beam **2033** at locations **2082** in a layer is uniform.

[0388] In this manner, controller **2014** can adjust a number of scan parameters **2070** such that the time to perform nearest neighbor scan **2042** can be performed within a desired amount of time. In other words, rather than having a longer dwell time along the entire path for nearest neighbor scan **2042**, the dwell time can decrease as the scan progresses. This change in dwell time can be made during the scan because the likelihood of satellite **2038** being in a location farther away from central location **2023** is lower than at central location **2023**.

[0389] Controller **2014** controls laser beam system **2030** to continue to move laser beam **2033** from current location **2025** to next location **2024** that is nearest neighbor **2044** to current location **2025** in response to not receiving confirmation **2027** that satellite **2038** has received laser beam **2033**.

[0390] In these examples, the moving or directing of laser beam **2033** can also be referred to as pointing laser beam **2033**. Further, laser beam **2033** can be selected from one of unidirectional communications and bidirectional communications.

[0391] In this example, confirmation **2027** can be received from satellite **2038**. Satellite **2038** can send a return laser beam at the same angle as the incoming laser beam.

[0392] In this illustrative example, controller **2014** can perform a number of operations in response to locating satellite **2038**. For example, controller **2014** can establish communications with satellite **2038** in response to receiving confirmation **2027** that satellite **2038** has received laser beam **2033**.

[0393] In one illustrative example, one or more technical solutions are present that overcome a technical problem with pointing an electromagnetic beam, such as a laser beam, at a receiver connected to a platform. As a result, one or more illustrative examples enable pointing a laser beam at an object in an efficient manner. The pointing of the laser beam is performed in a manner that adjusts a number of scan parameters during the scanning process used to scan an area such as search area **2081**.

[0394] Computer system **2012** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware, or a combination thereof. As a result, computer system **2012** operates as a special purpose computer system in which controller **2014** in computer system **2012** enables adjusting scan parameters such that locating an object can be performed more quickly as compared to current techniques. Controller **2014** transforms computer system **2012** into a special purpose computer system as compared to currently available general computer systems that do not have controller **2014**.

[0395] In the illustrative example, the use of controller **2014** in computer system **2012** integrates processes into a practical application for pointing electromagnetic beam **2003** at electromagnetic beam receiver **2004**. In these different examples, the processes adjusts scan parameters **2070** during movement of electromagnetic beam **2003**. In other words, the number of scan parameters **2070** are not fixed during the scanning of search area **2081**.

[0396] The illustration of electromagnetic signal environment **2000** in FIG. **20** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0397] For example, electromagnetic beam **2003** has been described as being laser beam **2033**. Electromagnetic beam **2003** can take other forms in other illustrative examples such as a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam.

[0398] As another example, object **2093** can take a number of different forms in addition to satellite **2038**. For example, object **2093** can be selected from a group comprising an uncooperative object, a platform, a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, an electromagnetic beam receiver, and other suitable types of objects.

[0399] As another example, controller **2014** can control one or more electromagnetic beam systems in addition to or in place of electromagnetic beam system **2020**. Further, the system can be used with an electromagnetic signal receiver system as described below with respect to FIG. **3**.

[0400] In one illustrative example, the number of scan parameters **2070** changes between concentric layers **2083**. In other illustrative examples, the number of scan parameters **2070** can change at other locations to scan search area **2081**. For example, the number of scan parameters **2070** can change within a layer in concentric layers **2083**. The locations at which the number of scan parameters **2070** change can be selected to increase the likelihood that electromagnetic beam **2003**, such as laser beam **2033**, hits object **2093**.

[0401] Pointing an electromagnetic signal receiver at an electromagnetic signal source can also take more time than desired and is more challenging than desired. With reference now to FIG. **21**, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment **2100** includes components that can be implemented in hardware such as the hardware shown in satellite **120** and receiver **122** and telescope **123** in FIG. **1**.

[0402] In the illustrative example, electromagnetic signal receiver system **2101** in electromagnetic signal environment **2100** can be pointed to receive electromagnetic signals **2103** from electromagnetic signal source **2104**. In this example, electromagnetic signal receiver system **2101** comprises electromagnetic signal receiver **2102** and controller **2114**. In this example, controller **2114** is located in computer system **2112**. As depicted, computer system **2112** is part of electromagnetic signal receiver system **2101** in this example. In this example, these components can be examples of components in electromagnetic signal receiver system **301** in FIG. **3**. The components can be implemented using components in electromagnetic signal receiver system **301** in FIG. **3**.

[0403] In this illustrative example, electromagnetic signal source **2104** generates electromagnetic signals **2103**. Electromagnetic signals **2103** can take a number of different forms. For example, electromagnetic signals **2103** can be in a beam, collimated beam, omnidirectional signals, directional signals, or other types of radiation patterns for forms. Electromagnetic signals **2103** can be selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, ultraviolet light signals, or other types of electromagnetic signals.

[0404] Electromagnetic signal source **2104** can take a number of different forms. For example, electromagnetic signal source **2104** can be a platform selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[0405] Electromagnetic signal receiver **2102** is a physical hardware system that can receive electromagnetic signals **2103**. Electromagnetic signal receiver **2102** has field of view **2121**. In this illustrative example, hardware such as an antenna, a radio receiver, a photo detector, or other device that can detect electromagnetic signals **2103** that are in field of view **2121** can be used. This hardware is unable to detect or use electromagnetic signals **2103** outside the field of view **2121**.

[0406] The hardware can include receiver **2183**. Receiver **2183** can be implemented using a receiver such as a photodetector, a photodiode system, a phase array antenna, focal plane array (FPA), cell (QC), or other suitable types of hardware.

[0407] In another illustrative example, electromagnetic signal receiver **2102** can include telescope **2182**. Telescope **2182** is a hardware component collecting incoming electromagnetic signals onto a detector in receiver **2183**.

[0408] In this illustrative example, field of view (FOV) **2121** is the view that electromagnetic signal receiver **2102** has to see or receive electromagnetic signals **2103**. Field of view **2121** may be described as the angular range within which electromagnetic signal receiver **2102** can detect or receive electromagnetic signals **2103**. In this example, field of view **2121** can be defined by telescope **2182**.

[0409] In this example, field of view **2121** can also be described as the instantaneous angle subtended by the scanning system that exceeds the detection threshold.

[0410] Controller **2114** can be implemented in a similar manner as controller **314** in FIG. **3** in which program instructions **2118** can be used to implement controller **2114** that are executed by a number of processor units **2116** in computer system **2112**. In this example, controller **2114** includes processes similar to those in controller **314** in FIG. **3** but also includes additional processes for controlling the manner in which a scan is performed to detect electromagnetic signals **2103**. Program instructions **2118**, the number of processor units **2016**, and computer system **2112** can be implemented in a similar manner to program instructions **318**, processor units **316**, and the computer system **312** in FIG. **3**.

[0411] Controller **2114** is configured to control the operation of electromagnetic signal receiver **2102**. For example, controller **2114** can control electromagnetic signal receiver **2102** in search area **2181**. Search area **2181** is an area in which electromagnetic signal source **2104** is believed to be present. This search can be performed by moving field of view **2121** to scan search area **2181**.

[0412] In one illustrative example, search area **2181** comprises locations **2192** around central location **2123** that are arranged in concentric layers **2193** in search area **2081**. These layers can also be referred to as rings and in particular as concentric rings. Each layer in concentric layers **2193** is larger or farther away from central location **2123** than a prior layer in concentric layers **2193**. Central location **2123** can be considered a first layer in concentric layers **2193**.

[0413] In this illustrative example, controller **2114** controls electromagnetic signal receiver **2102** to move field of view **2121** of electromagnetic signal receiver **2102** to central location **2123** in search area **2181** in which electromagnetic signal source **2104** is expected to be located. This moving of field of view **2121** can also be referred to as pointing field of view **2121**. Central location **2123** is the first location for performing hexagonal scan **2140** and is at the center of search area **2081**. Hexagonal scan **2140** occurs from moving field of view **2121** to scan search area **2181**.

[0414] Further, in this example, controller **2114** moves field of view **2121** of electromagnetic signal receiver **2102** to next location **2124** that is nearest neighbor **2144** to central location **2123** in response to not detecting electromagnetic signals **2103** from electromagnetic signal source **2104** at central location **2123**. In this example, next location **2124** becomes current location **2125** for field of view **2121**. This type of movement of field of view **2121** is nearest neighbor scan **2142**. Thus, the movement of field of view **2121** can be both hexagonal scan **2140** and nearest neighbor scan **2142**.

[0415] Thus, with this type of movement, the scan performed by moving field of view **2121** is both hexagonal scan **2040** and nearest neighbor scan **2042**.

[0416] Further in this example, controller **314** adjusts a number of scan parameters **2170** during a movement of field of view **2121** to scan search area **2181**. In this illustrative example, the number of scan parameters **2170** can be adjusted by controller **2114** controlling electromagnetic signal receiver **2102**. The number of scan parameters **2170** can be selected from at least one of overlap **2171**, beam divergence **2172**, dwell time **2173**, or other suitable scan parameters. In this illustrative example, the number of scan parameters **2170** can be adjusted to increase the likelihood that electromagnetic signals **2103** from electromagnetic signal source **2104** are detected.

[0417] In this illustrative example, the number of scan parameters **2170** can be changed during movement of field of view **2121** using the same type of adjustments as described with respect to controller **2014** adjusting scan parameters **2070** while controlling laser beam system **2030** to move laser beam **2033** to scan search area **2081** in FIG. **20**.

[0418] In this illustrative example, controller **2114** can detect electromagnetic signals **2103** from electromagnetic signal source **2104** in response to detecting selected electromagnetic signals that are greater than a noise level in field of view **2121**. In response to detecting electromagnetic signals **303**, controller **2114** can establish communications with electromagnetic signal source **2104** or perform other actions. As another example, controller **2114** can identify a location of electromagnetic signal source **2104** in response to detecting electromagnetic signals **2103** in a particular location in locations **2192** in search area **2181**.

[0419] The illustration of electromagnetic signal environment **2100** in FIG. **21** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0420] For example, electromagnetic signal receiver system **2101** can be connected to platform **2105**. In this example, platform **2105** can be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0421] In another illustrative example, controller **2114** can be located in a separate platform or location from electromagnetic signal receiver system **2101**. Additionally, electromagnetic signal receiver system **2101** can be used with an electromagnetic signal transmission system such as electromagnetic beam transmission system **2002** in FIG. **20**. In this example, a single controller can be present that controls both systems and that controller can be in a separate location from the systems.

[0422] In yet another illustrative example, controller **2114** can be controlled by one or more electromagnetic signal receiver systems in addition to or in place of electromagnetic signal receiver system **2101**.

[0423] Further with this example, search area **2181** is a shape of hexagon **2191**. In other examples, the scan area can have a shape selected from a group comprising a hexagon, a circle, an octagon, an ellipse, or some other suitable shape in addition to or in place of hexagon **2191**.

[0424] With reference next to FIG. **22**, an illustration of hexagonal scans performed using scan parameters that are adjusted during the scanning of a search area is depicted in accordance with an illustrative embodiment. In this illustrative example, hexagonal scans **2200** are hexagonal scans in which a number of scan parameters are adjusted for hexagonal scan **2201** while performing a scan. In other words, one or more scan parameters can change during the performance of the scan of the search area.

[0425] As depicted, spiral scans **2202** include spiral scan **2221**, spiral scan **2222**, and spiral scan **2223**. These spiral scans provide a visual illustration of adjustments to scan parameters that occur during the performance of these spiral scans. In this example, spiral scans **2202** have been selected because the scans provide a clear visualization of changes to scan parameters.

[0426] In this example, these spiral scans include illustrative adjustments to overlap **2211**, beam divergence **2212**, and dwell time **2213**. As depicted, overlap **2211** decreases as spiral scan **2221** progresses. Further in this example, beam divergence **2212** increases as spiral scan **2222** progresses. Further in this example, dwell time **2213** decreases as spiral scan **2223** progresses.

[0427] In this example, hexagonal scan **2231** is hexagonal scan **2201** with adjustments to overlap **2211**. In this example, the overlap decreases as hexagonal scan **2231** progresses. In this example, the increase in overlap occurs at each layer in the concentric layers forming hexagonal scan **2231**.

[0428] In this example, hexagonal scan **2241** is hexagonal scan **2201** with adjustments to beam divergence **2212**. In this example, beam divergence **2212** increases as hexagonal scan **2241** progresses. In this example, the increase in beam divergence **2212** occurs at each layer in the concentric layers forming hexagonal scan **2241**.

[0429] Further, hexagonal scan **2251** is hexagonal scan **2201** with adjustments to dwell time **2213**. In this example, dwell time **2213** increases as hexagonal scan **2251** progresses. In this example, the increase in dwell time **2213** occurs at each layer in the concentric layers forming hexagonal scan **2251**.

[0430] In this illustrative example, the adjustments to the number of scan parameters are performed to reduce the amount of time needed to perform a scan as compared to maintaining the same value for scan parameters of the entire scan. As a result, scans can be performed with a greater likelihood of hitting an object such as a satellite while performing scans within a selected amount of time. This selected amount time may be set through various policies such as service-level agreements, scan time requirements or other rules or guidelines.

[0431] Turning to FIG. **23**, an illustration of a hexagon scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan **2231** is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved to perform hexagonal scan **2231**.

[0432] For example, hexagonal scan **2231** starts at central location **2301** and moves from location to location in layers that form concentric layers **2300**.

[0433] As depicted, the beam spots are organized as concentric layers **2300** around central location **2301**. In this example, concentric layers **2300** comprises five concentric layers, which has central location **2301**, layer **2321**, layer **2322**, layer **2323**, and layer **2324**. Each layer in concentric layers **2300** is thicker than the previous layer in concentric layers **2300**. For example, layer **2322** is thicker than layer **2321**. In this example, central location **2301** is the innermost layer and layer **2324** is the outermost layer in concentric layers **2300**.

[0434] As depicted, a dashed line in a layer in a hexagonal shape extends through the center of beam spots. In this example, each of concentric layers **2300** has a hexagonal shaped dashed line. The dashed lines represents a path of the laser beam through each of the layers. Each layer in these concentric layers can be also referred to as a zone or sector around central location **2301**.

[0435] In this example, overlap **2370** between locations in adjacent layers decreases during movement of the laser beam in performing hexagonal scan **2231**. In this depicted example, the overlap **2370** decreases at each layer in concentric layers **2300**. With this example, as the layers in concentric layers **2300** become thicker, overlap **2370** decreases.

[0436] In this example, overlap **2370** for a selected layer is the overlap between the selected layer and another layer in hexagonal scan **2231**. The layer can be a prior layer or a subsequent layer.

[0437] For example, overlap **2370** for layer **2322** has width **2360**, which is the overlap between locations in layer **2322** and locations in layer **2321**. In other words, the overlap **2370** in a current layer is the overlap between locations that form the current layer and locations in the prior layer that was previously scanned.

[0438] In another example, overlap **2370** can be with a current layer and a subsequent layer that will be scanned. For example, overlap **2370** for layer **2322** can be the overlap between locations in layer **2322** and locations in layer **2323**. Overlap **2370** can reduce issues caused to vibrations at the source of the laser beam. For example, vibrations in a laser beam system can cause the laser beam to have jitter such that the laser beam does not hit the intended location at which the laser beam is directed or pointed. Overlap **2370** can increase the likelihood that the laser beam hits the object even with jitter in the laser beam.

[0439] For example, an object such as a satellite is at a first location. The laser beam directed to the first location may result in a miss because of the jitter in the laser beam. However, the overlap of the first location from a second location increases the probability that the satellite will be hit when the laser beam is directed at the second location For example, the laser beam may miss the satellite while moving layer **2322**. The laser beam may hit the satellite while moving along layer **2323** because of overlap **2370** between layer **2322** and layer **2323**.

[0440] In this example, overlap **2370** for layer **2323** is the overlap between locations in layer **2323** and locations in layer **2322**. In this example, the overlap has width **2361**.

[0441] As depicted, width **2360** of the overlap for layer **2322** is greater than width **2361** for layer **2323**. In this example, the overlap decreases as the scan progresses outwards through concentric layers **2300** in hexagonal scan **2231**.

[0442] In this example, overlap can be referred to as a path overlap and can be used to increase the probability of detecting an object such as a satellite while minimizing the time to scan an area such as a hexagonal shape or other areas with other shapes. In these examples, increasing overlap between the layers or sections in a scan increases the probability that an object will be detected in those layers or sections. In these examples, the probability of detecting the object is dependent in part on overlap of a layer with an adjacent layer.

[0443] With reference to FIG. 24, an illustration of a hexagon scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan 2241 has adjustments to beam divergence that change during performance of hexagonal scan 2241. In this example, hexagonal scan 2231 is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved to perform hexagonal scan 2031.

[0444] For example, hexagonal scan 2241 starts at central location 2401 and moves from location to location in layers that form concentric layers 2400.

[0445] As depicted, these beam spots are organized as concentric layers 2300 around central location 2301. In this example, concentric layers 2400 comprises five concentric layers. Central location 2301 is the first layer. The other four layers are layer 2421, layer 2422, layer 2423, and layer 2424. Each layer in concentric layers 2300 is thicker than the previous layer in concentric layers 2300. For example, layer 2322 is thicker than layer 2321. In this example, central location 2401 is the innermost layer and layer 2424 is the outermost layer in concentric layers 2400.

[0446] In this example, beam divergence increases from layer to layer in concentric layers 2400. As a result, the size of beam spot in a plane increases from layer to layer in concentric layers 2400 during the performance of hexagonal scan 2241.

[0447] For example, a low irradiance laser beam is harder to detect than a high irradiance laser beam. Also increasing the beam divergence (i.e., larger spot size) of a laser beam reduces the irradiance of the laser beam. As a result, hitting an object such as a satellite becomes more difficult as the beam spot size of the laser beam increases from changing the beam divergence. Increasing the spot size through increased beam divergence enables covering more of the scan area as compared to a smaller spot size. As a result, scan time can decrease as the beam divergence increases for a scan area.

[0448] A limited amount of time can be present for completing a scan of an area. With this limitation in mind, it is desirable to maximize the probability that the laser beam will hit the target and the target will detect the laser beam. In these examples, the object is expected to be near the center of the area being scanned. As a result, a higher laser beam irradiance is used when scanning the center of the area as compared to outer portions of the area. As a result, the beam spot should be small (i.e., low beam divergence). A small beam divergence takes more time to scan as compared to a larger beam divergence.

[0449] This changing to the beam divergence can be performed to decrease the time needed to scan the area. In these examples, the probability that the object is located near the edge of the area being scanned is lower as compared to the center of the area being scanned. As a result, beam divergence can be increased to increase beam spot size at the edge of the area to reduce the scan time for scanning area at portions of the area farther away from the center. As a result, increasing the beam divergence can reduce scan time. This saved scan time can be used to scan near the center. In other words, resources are shifted away from the portions of the area being scanned that are less likely to contain the object to scan the portions where the object is more likely to be present. The use of the increased beam divergence results in the beam being less likely to hit the object and the object being less likely to detect the laser beam when the object is located on the edge of the area being scanned. This lower probability of hitting an object is made up by the increased probability of hitting the object at the center of the area being scanned.

[0450] In another example, if a required probability of hitting and detection by the object is specified, the time for scanning can be traded for the probability to minimize scan time.

[0451] Next in FIG. 25, an illustration of a hexagon scan with decreasing dwell time is depicted in accordance with an illustrative embodiment. In this example, hexagonal scan 2251 has adjustments to dwell time that change during performance of hexagonal scan 2251. In this example, hexagonal scan 2231 is comprised of beam spots. In this illustrative example, each circle represents the location of the beam spot for a laser beam that is moved from location to location to perform hexagonal scan 2251.

[0452] For example, hexagonal scan 2241 starts at central location 2401 and moves from location to location in layers that form concentric layers 2500.

[0453] As depicted, these beam spots are organized as concentric layers 2500 around central location 2501. In this example, concentric layers 2500 comprises five concentric layers. Central location 2501 is the first layer. The other four layers are layer 2521, layer 2522, layer 2523, and layer 2524. In this example, each layer in concentric layers 2500 has a dwell time that is less than the dwell time in a previous layer in concentric layers 2500.

[0454] In this illustrative example, the dwell time increases as hexagonal scan 2251 progresses. More specifically, the dwell time for the laser beam decreases at each layer in concentric layers 2500. For example, the dwell time used for layer 2521 is greater than the dwell time for layer 2522.

[0455] In these illustrative examples, increased dwell time increases the probability that an object such as a satellite can be detected in the search of an area such as a search area. For example, the amount of time to aim a beam at an object is dwell time. As the dwell time increases, the probability that the object will be hit by the laser beam and that the laser beam will be detected by the target increases. Increasing dwell time results in increasing the scan time.

[0456] In the illustrative example a set amount of time can be present to complete a scan of an area. Further, it is desirable to maximize the probability that an object such as a satellite will be hit by the laser beam and that the satellite will detect the laser beam. With this example, the satellite is expected to be near the center of the area being scanned. As a result, a laser dwell time is used when scanning near the center. However, with limited scan time, the dwell time can be reduced in other portions of the area being scanned to avoid increasing the scan time from increasing the dwell time. In this depicted example, the satellite is not expected to be near the edge of the area. As a result, the dwell time can be decreased at the edge. This reduction in scan time for this portion can offset the increase in scan time near the center of the area. In other words, resources (dwell time) are shifted away from portions of the scan area that are less likely to contain the satellite to portions of the area where the satellite is more likely to be present. The reduction of the dwell time results in reducing the likelihood that the laser beam will hit and be detected by a satellite located on the edge of the area. This reduction in probability is offset by increasing the probability of the laser beam hitting and being detected by the satellite close to the center of the area being searched, where the satellite is expected to be located.

[0457] In this illustrative example, greater dwell times can be used in areas in which the object is more likely to be found as compared to areas in which the object is less likely to be found. In this manner, a hexagonal scan can be performed without increasing the amount of scan time.

[0458] The illustration of changing scan parameters in FIGS. **22-25** for a hexagonal scan is provided as one example and not meant to limit the manner in which other illustrative examples can be implemented. For example, although the scan parameters change at each layer, the scan parameters can change while scanning is performed within a layer. For example, scan parameters can change within a layer in the concentric layers. For example, a portion or segment of a layer can have one overlap while another portion or segment of the same layer can have a different overlap.

[0459] Further, one or more scan parameters can be changed during a hexagonal scan in addition to the scan parameters illustrated in these hexagonal scans. In other illustrative examples, other types of electromagnetic beams can be used in addition to the laser beam. For example, the electromagnetic beam used in the scans can be selected from a group comprising a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam. Further, these type of scans can also be used in receiving electromagnetic signals from an electromagnetic signal source.

[0460] Turning to FIG. **26**, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. **26** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **2014** in computer system **2012** in FIG. **20**.

[0461] The process begins by directing the electromagnetic beam at a central location in a search area in which an object is expected to be located (operation **2600**). The process moves the electromagnetic beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the object is at the central location, wherein the next location becomes a current location for the electromagnetic beam (operation **2602**).

[0462] The process adjusts a number of scan parameters during a movement of the electromagnetic beam to scan the search area (operation **2604**). The process continues to move the electromagnetic beam from the current location to the next location that is a nearest neighbor to the current location in response to not receiving the confirmation that the object has received the electromagnetic beam (operation **2606**). The process terminates thereafter.

[0463] Turning to FIG. **27**, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. **27** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **2014** in computer system **2012** in FIG. **20**.

[0464] The process directs the laser beam at a central location in a search area in which a satellite is expected to be located (operation **2700**). The process moves the laser beam to a next location that is a nearest neighbor to the central location in response to not receiving a confirmation that the satellite is at the central location, wherein the next location becomes a current location for the laser beam (operation **2702**).

[0465] The process adjusts a number of scan parameters during a movement of the laser beam to scan the search area (operation **2704**). In operation **2704**, the number of scan parameters can be changed during every movement of the laser beam or during one or more movements of the laser beam to the scan search area **2081**. For example, the number of scan parameters can be changed from location to location. The adjustment to the number of scan parameters is made to efficiently search for a satellite. In some cases, the scan parameters can be changed between some locations and not all of the locations.

[0466] The process continues to move the laser beam from the current location to the next location that is the nearest neighbor to the current location in response to not receiving the confirmation that the satellite has received the laser beam (operation **2706**). The process terminates thereafter.

[0467] Next in FIG. **28**, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **2704** in FIG. **27**.

[0468] The process decreases an overlap during the movement of the laser beam to scan the search area (operation **2800**). The process terminates thereafter.

[0469] With reference now to FIG. **29**, an illustration of a flowchart of a process for decreasing overlap is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **2800** in FIG. **28**.

[0470] The process decreases the overlap at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the overlap at locations in a layer is uniform (operation **2900**). The process terminates thereafter.

[0471] Next in FIG. **30**, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **2704** in FIG. **27**.

[0472] The process increases a beam divergence of the laser beam during the movement of the laser beam to scan the search area (operation **3000**). The process terminates thereafter.

[0473] With reference now to FIG. **31**, an illustration of a flowchart of a process for increasing beam divergence is depicted in accordance with an illustrative embodiment. Process in this flowchart is an example of an implementation for operation **3000** in FIG. **30**.

[0474] The process increases the beam divergence of the laser beam at each layer during the movement of the laser beam to scan the search area, wherein the beam divergence of the laser beam at locations in a layer is uniform (operation **3100**). The process terminates thereafter.

[0475] Turning next to in FIG. **32**, an illustration of a flowchart of a process for adjusting a number of scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **2704** in FIG. **27**.

[0476] The process decreases a dwell time for the laser beam during the movement of the laser beam to scan the search area (operation **3200**). The process terminates thereafter.

[0477] Next in FIG. **33**, an illustration of a flowchart of a process for decreasing dwell time is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **3200** in FIG. **32**.

[0478] The process decreases the dwell time for the laser beam at each layer in concentric layers in the search area during the movement of the laser beam to scan the search area, wherein the dwell time of the laser beam at locations in a layer is uniform (operation **3300**). The process terminates thereafter.

[0479] With reference next to FIG. **34**, an illustration of a flowchart of a process for receiving electromagnetic signals is depicted in accordance with an illustrative embodiment. The process in FIG. **34** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one or more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **2114** in computer system **2112** in FIG. **21**.

[0480] The process moves a field of view of an electromagnetic signal receiver to a central location in a search area in which an electromagnetic signal source is expected to be located (operation **3400**). The process moves the field of view to a next location that is a nearest neighbor to the central location in response to not detecting electromagnetic signals from the central location, wherein the next location becomes a current location for the field of view (operation **3402**).

[0481] The process adjusts a number of scan parameters during a movement of the field of view to scan the search area (operation **3404**). The process continues to move the field of view from the current location to the next location that is the nearest neighbor to the current location in response to not detecting electromagnetic signals (operation **3406**). The process terminates thereafter.

[0482] The flowcharts and block diagrams in the different depicted examples in FIGS. **26-34** illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative example. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0483] 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.

[0484] With reference now to FIG. **35**, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment **3500** includes components that can be implemented in hardware such as the hardware in satellite **101** and satellite **102** in FIG. **1**.

[0485] In this example, electromagnetic beam transmission system **3502** is an example of an implementation of electromagnetic beam transmission system **202** in FIG. **2**. The components can be implemented using components in electromagnetic beam transmission system **202** in electromagnetic signal environment **200** in FIG. **2**.

[0486] In this illustrative example, electromagnetic beam transmission system **3502** can point the transmission of electromagnetic beam **3503** at object **3593**. In this example, object **3593** can be electromagnetic beam receiver **3504**. Object **3593** can also be platform **3505** with which electromagnetic beam receiver **3504** is connected in this example.

[0487] In this illustrative example, electromagnetic beam transmission system **3502** comprises electromagnetic beam system **3520** and controller **3514**. In this example, controller **3514** is located in computer system **3512**. As depicted, computer system **3512** is also part of electromagnetic beam transmission system **3502**.

[0488] Electromagnetic beam system **3520** is a physical hardware system. This hardware system is configured to transmit electromagnetic beam **3503**.

[0489] Controller **3514** can be implemented in a similar manner as controller **214** in FIG. **2** in which program instructions **3518** can be used to implement controller **3514** that are executed by a number of processor units **3516** in computer system **3512**. In this example, controller **2014** includes processes similar to those in controller **214** in FIG. **2** but also includes additional processes for controlling the manner in which a scan is performed. Program instructions **3518**, the number of processor units **3516**, and computer system **3512** can be implemented in a similar manner to program instructions **218**, processor units **216**, and computer system **212** in FIG. **2**.

[0490] In this illustrative example, controller **3514** controls electromagnetic beam transmission system **3502** to direct electromagnetic beam **3503** at location **3522** nearest to maximum **3523** of uncertainty area **3581** in which object **293** is expected to be located. In other words, uncertainty area **3581** is an area in which object **3593** is believed to be present. However, object **3593** may not actually be in uncertainty area **3581**. In some cases, uncertainty area **3581** can be selected as an area for searching with the hope of locating object **3593**.

[0491] Further in this example, maximum **3523** represents a probability that object **3593** is at a location (beam spot) covered by electromagnetic beam system **3520**. Maximum **3523** does not need to be 100 percent but can be some lower percentage.

[0492] As depicted, electromagnetic beam **3503** has beam spot **3561**. In this example, beam spot **3561** is a diameter of electromagnetic beam **203** at a location in uncertainty area **3581**. In this example, beam spots can correspond to locations in uncertainty area **3581**. For example, location **3522** in uncertainty area **3581** can have a size and shape that corresponds to beam spot **3561** when the electromagnetic beam **3503** is directed at location **3522**.

[0493] Location **3522** nearest to maximum **3523** of uncertainty area **3581** can be determined using a probability density function (PDF) that shows what location is likely to be closest to maximum **3523**.

[0494] In this example, controller **3514** controls electromagnetic beam system **3520** to move electromagnetic beam **3503** from location **3522** to next location **3524** nearest to maximum **3523** of uncertainty area **3581** in response to not receiving confirmation **3527** that object **3593** such as electromagnetic beam receiver **3504** is at location **3522**. In this example, next location **3524** becomes current location **3525** for electromagnetic beam **3503**.

[0495] Further in this example, controller **3514** adjusts a number of scan parameters **3570** during a movement of electromagnetic beam **3503** to scan uncertainty area **3581**. In this illustrative example, the number of scan parameters **3570** can be adjusted by controller **3514** controlling electromagnetic beam system **3520**. In this illustrative example, the number of scan parameters **3570** can be adjusted to increase the likelihood that electromagnetic beam **3503** hits object **3593** in uncertainty area **3581**.

[0496] Controller **3514** controls electromagnetic beam system **3520** to continue to move electromagnetic beam **3503** from current location **3525** to next location **3524** nearest to maximum **3523** of uncertainty area **3581** from current location **3525** in response to not receiving a confirmation **3527** that electromagnetic beam **3503** has encountered object **3593**, such as electromagnetic beam receiver **3504** receiving electromagnetic beam **3503**. This type of movement of electromagnetic beam **3503** is nearest to maximum scan **3540**. When maximum **3523** of uncertainty area **3581** is the center of uncertainty area **3581**, nearest to maximum scan **3540** is nearest to center scan **3597**. This is an example of an implementation for nearest to maximum scan **3540** in which maximum **3523** of uncertainty area **3581** is the center of uncertainty area **3581**.

[0497] In one illustrative example, electromagnetic beam **3503** can take the form of laser beam **3533**. Further, laser beam **3533** can be selected from a group comprising a continuous laser beam and a pulsed laser beam. Electromagnetic beam system **3520** can be laser beam system **3530** and platform **3505** can take the form of satellite **3538**. In this example, electromagnetic beam transmission system **3502** is laser beam transmission system **3511**.

[0498] In this example, controller **3514** controls laser beam system **3530** to direct laser beam **3533** at location **3522** nearest to maximum **3523** of uncertainty area **3581** in which satellite **3538** is expected to be located. Controller **3514** also controls laser beam system **3530** to move laser beam **3533** from location **3522** to next location **3524** nearest to maximum **3523** of uncertainty area **3581** in response to not receiving confirmation **3527** that satellite **3538** is at location **3522**. In this example, next location **3524** becomes current location **3525** for laser beam **3533**.

[0499] Further, controller **3514** adjusts a number of scan parameters **3570** during a movement of laser beam **3533** to scan uncertainty area **3581**. In this illustrative example, the number of scan parameters **3570** can be adjusted to increase the likelihood that laser beam **3533** hits satellite **3538** in uncertainty area **3581**. The number of scan parameters **3570** can be selected from at least one of overlap **3571**, beam divergence **3572**, dwell time **3573**, or other suitable scan parameters.

[0500] In adjusting the number of scan parameters **3570**, controller **3514** decreases overlap **3571** during the movement of laser beam **3533** to scan uncertainty area **3581**. With this example, maximum **3523** of uncertainty area **3581** is a center of uncertainty area **3581**. Further, overlap **3571** at locations that have a same distance from the maximum of the uncertainty area is uniform. In other words, each location in the locations having the same distance from the center of uncertainty area **3581** have the same overlap. Locations having the same distance from the center of uncertainty area **3581** form a group of locations. Each group of locations having longer distance from the center of uncertainty area **3581** have a greater overlap.

[0501] Further, In adjusting the number of scan parameters **3570**, controller **3514** increases beam divergence **3572** of laser beam **3533** during the movement of laser beam **3533** to scan uncertainty area **3581**. In this example, maximum **3523** of uncertainty area **3581** is a center of uncertainty area **3581**. Further with this example, beam divergence **3572** of laser beam **3533** at locations that have a same distance from maximum **3523** of uncertainty area **3581** is uniform.

[0502] In adjusting the number of scan parameters **3570**, controller **3514** decreases dwell time **3573** for laser beam **3533** during movement of laser beam **3533** to scan uncertainty area **3581**. With this example, maximum **3523** of uncertainty area **3581** is a center of uncertainty area **3581**. Dwell time **3573** of laser beam **3533** at locations that have a same distance from the maximum **3523** of uncertainty area **3581** is uniform.

[0503] Controller **3514** controls laser beam system **3530** to continue to move laser beam **3533** from current location **3525** to next location **3524** nearest to maximum **3523** of uncertainty area **3581** from current location **3525** in response to not receiving confirmation **3527** that satellite **3538** has received laser beam **3533**. The moving or directing of laser beam **3533** can also be referred to as pointing laser beam **3533**. Further, laser beam **3533** can be selected from one of unidirectional communications and bidirectional communications.

[0504] In this example, confirmation **3527** can be received from satellite **3538**. For example, satellite **3538** sends a return laser beam at the same angle as the incoming laser beam.

[0505] In this example, the movement controlled by controller **3514** is nearest to maximum scan **3540** such as nearest to maximum hexagonal scan **3541**. With this example, uncertainty area **3581** can be in a shape of hexagon **3591** for nearest to maximum hexagonal scan **3541**. Further, controller **3514** can control the movement of laser beam **3533** to change from nearest to maximum scan **3540** to nearest neighbor scan **3542**. This type of scan in which the scanning changes from nearest to maximum scan **3540** to nearest neighbor scan **3542** is hybrid scan **263**.

[0506] For example, controller **3514** moves laser beam **3533** to neighbor location **3543** of nearest neighbor **3544** in response to time **3548** for moving laser beam **3533** from current location **3525** to next location **3524** using location **3522** nearest to maximum **3523** of uncertainty area **3581** being greater than threshold **3547**. In this example, next location **3524** becomes current location **3525** for future movements.

[0507] In this case, threshold **3547** can be selected as the time for moving laser beam **3533** from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time.

[0508] Further in this example, controller **3514** continues to move laser beam **3533** from current location **3525** to subsequent neighbor location **3545** of nearest neighbor **3544** from current location **3525** in response to time **3548** for moving laser beam **3533** from current location to next location **3524** using location **3522** nearest to maximum **3523** of uncertainty area **3581** being greater than threshold **3547** and in response to not receiving confirmation **3527** that satellite **3538** has received laser beam **3533**.

[0509] As a result, controller **3514** changes from using nearest to maximum scan **3540** to nearest neighbor scan **3542**. This type of hybrid scan can provide a faster location of satellite **3538** as compared to just using nearest to maximum scan **3540**.

[0510] In moving laser beam **3533** to neighbor location **3543** of nearest neighbor **3544** and continuing to move laser beam **3533** from current location **3525** to subsequent neighbor location **3545** of nearest neighbor **3544** from current location **3525** is part of a nearest neighbor scan **3542** selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, a hexagonal scan, and a raster scan.

[0511] In response to receiving confirmation **3527**, controller **3514** establishes communications with satellite **3538**. The communication is selected from one of unidirectional communications and bidirectional communications.

[0512] In one illustrative example, one or more technical solutions are present that overcome a technical problem with pointing an electromagnetic beam, such as a laser, at a receiver. As a result, one or more illustrative examples enable scanning an area such as an uncertainty area in an efficient manner. The number of scan parameters can be adjusted during the scanning of the uncertainty area in a manner that increases the likelihood of hitting an object. In some examples, a hybrid scan can be used.

[0513] Computer system **3512** can be configured to perform at least one of the steps, operations, or actions described in the different illustrative examples using software, hardware, firmware, or a combination thereof. As a result, computer system **3512** operates as a special purpose computer system in which controller **3514** in computer system **3512** enables adjusting scan parameters such that locating an object can be performed more quickly as compared to current techniques. Controller **3514** transforms computer system **3512** into a special purpose computer system as compared to currently available general computer systems that do not have controller **3514**.

[0514] The illustration of electromagnetic signal environment **3500** in FIG. **35** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0515] For example, electromagnetic beam **3503** has been described as being laser beam **3533**. Electromagnetic beam **3503** can take other forms in other illustrative examples. For example, electromagnetic beam **3503** can be selected from a group comprising laser beam **3533**, a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam.

[0516] As another example, platform **3505** can take a number of different forms in addition to satellite **3538**. For example, electromagnetic beam receiver **3504** can be located in platform **3505** selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a vehicle controlled by an artificial intelligence system, a vehicle controlled by a neural network, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0517] As another example, uncertainty area **3581** can take other shapes in addition to hexagon **3591**. For example, uncertainty area **3581** can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape. Controller **3514** can control one or more electromagnetic beam systems in addition to or in place of electromagnetic beam system **3520**. Further, the system can be used with an electromagnetic signal receiver system as described below with respect to FIG. **36**.

[0518] In these examples, pointing electromagnetic signal receiver at an electromagnetic signal source can also take more time than desired and is more challenging than desired.

[0519] With reference now to FIG. **36**, an illustration of a block diagram of an electromagnetic signal environment is depicted in accordance with an illustrative embodiment. In this illustrative example, electromagnetic signal environment **3600** includes components that can be implemented in hardware such as the hardware shown in satellite **120** and receiver **122** and telescope **123** in FIG. **1**.

[0520] In the illustrative example, electromagnetic signal receiver system **3601** in electromagnetic signal environment **3600** can be pointed to receive electromagnetic signals **3603** from electromagnetic signal source **3604**. In this example, electromagnetic signal receiver system **3601** comprises electromagnetic signal receiver **3602** and controller **3614**. In this example, controller **3614** is located in computer system **3612**. As depicted, computer system **3612** is part of electromagnetic signal receiver system **3601** in this example. In this example, these components can be examples of components in electromagnetic signal receiver system **301** in FIG. **3**. The components can be implemented using components in electromagnetic signal receiver system **301** in FIG. **3**.

[0521] In this illustrative example, electromagnetic signal source **3604** generates electromagnetic signals **3603**. Electromagnetic signals **3603** can take a number of different forms. For example, electromagnetic signals **303** can be a beam, collimated beam, omnidirectional signals, directional signals, or other types of radiation patterns for forms. Electromagnetic signals **3603** can be selected from at least one of a laser beam, a radio frequency beam, a microwave beam, microwave signals, infrared signals, visible light signals, ultraviolet light signals, or other types of electromagnetic signals.

[0522] Electromagnetic signal source **3604** can take a number of different forms. For example, electromagnetic signal source **3604** can be a platform selected from a group comprising a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, and a building.

[0523] Electromagnetic signal receiver **3602** is a physical hardware system that can receive electromagnetic signals **3603**. Electromagnetic signal receiver **3602** has field of view **3621**. In this illustrative example, hardware such as an antenna, radio receiver, photo detector, or other device that can detect electromagnetic signals **3603** that are in field of view **3621**. This hardware is unable to detect or use electromagnetic signals **3603** outside the field of view **3621**. The hardware can include receiver **3683**. Receiver **3683** can be implemented using a receiver such as a photodetector, a photodiode system, a phase array antenna, focal plane array (FPA), cell (QC), or other suitable types of hardware.

[0524] In another illustrative example, electromagnetic signal receiver **3602** can include telescope **3682**. Telescope **3682** is a hardware component collecting incoming electromagnetic signals onto a detector in receiver **3683**.

[0525] In this illustrative example, field of view (FOV) **3621** is the view that electromagnetic signal receiver **3602** has to see or receive electromagnetic signals **3603**.

[0526] In some illustrative examples, the size of field of view **3621** can be controlled. Field of view **3621** can have a size that enables detecting electromagnetic signals **3603**. For example, the time for nearest to maximum scan **3640** to locate electromagnetic signal source **3604** is faster than current techniques such as those that use a continuous file scan, a segment scan, or raster scan. However, actually detecting electromagnetic signals **3603** may be difficult with electromagnetic signals **3603** being too weak for detection with the size of field of view **3621**. For example, the aperture or coping defining the field of view for a receiver may pick up signals from other sources for noises in addition to the signals from the desired source. As a result, the receiver may struggle to identify and isolate electromagnetic signals **3603** from the surrounding noise. As a result, reducing or narrowing field of view **3621** can be performed to reduce issues with noise. In other words, size of field of view **3621** can be adjusted to increase the signal-to-noise ratio.

[0527] In another example, the scan time becomes slower as field of view **3621** is decreased. At some point, field of view **3621** may be able to easily detect electromagnetic signals **3603**. However, the amount of scan time may be much slower than desired and may be slower than current techniques.

[0528] The size of field of view **3621** can be selected such that electromagnetic signals **3603** can be just barely detectable. In other words, these electromagnetic signals can be detected over noise that may be present. With this selection of the size for field of view **3621**, nearest to maximum scan **3640** can be performed within a desired amount of time such as less than techniques that use a continuous scan based on a nearest neighbor.

[0529] Controller **3614** can be implemented in a similar manner as controller **314** in FIG. **3** in which program instructions **3618** can be used to implement controller **3614** that are executed by a number of processor units **3616** in computer system **3612**. In this example, controller **3614** includes processes similar to those in controller **314** in FIG. **3** but also includes additional processes for controlling the manner in which a scan is performed to detect electromagnetic signals **3603**. Program instructions **3618**, the number of processor units **3616**, and computer system **3612** can be implemented in a similar manner to program instructions **318**, processor units **316**, and computer system **312** in FIG. **3**.

[0530] Controller **3614** is configured to control the operation of electromagnetic signal receiver **3602**. In this illustrative example, controller **3614** controls electromagnetic signal receiver **3602** to move field of view **3621** of electromagnetic signal receiver **3602** to location **3622** nearest to maximum **3623** of uncertainty area **3681** in which an electromagnetic signal source **3604** is expected to be located. This moving of field of view **3621** can also be referred to as pointing field of view **3621**.

[0531] Further, in this example, controller **3614** moves field of view **3621** of electromagnetic signal receiver **3602** from location **3622** to next location **3624** nearest to maximum **3623** of uncertainty area **3681** in response to not detecting electromagnetic signals **3603** from electromagnetic signal source **3604** at location **3622**. In this example, next location **3624** becomes current location **3625** for field of view **3621**.

[0532] Controller **3614** adjusts a number of scan parameters **3670** during a movement of field of view **3621** to scan uncertainty area **3681**. The number of scan parameters **3670** changes during scanning of uncertainty area **3681**. In other words, the number of scan parameters **3670** does not remain fixed during the entire scan.

[0533] The number of scan parameters **3670** can be selected from at least one of overlap **3671**, beam divergence **3672**, dwell time **3673**, or other suitable scan parameters. In this illustrative example, the number of scan parameters **3670** can be adjusted to increase the likelihood that electromagnetic signals **3603** from electromagnetic signal source **3604** are detected.

[0534] In this illustrative example, the number of scan parameters **3670** can be changed during movement of field of view **3621** using the same type of adjustments as described with respect to controller **3514** adjusting scan parameters **3570** while controlling laser beam system **3530** to move laser beam **3533** to scan uncertainty area **3581** in FIG. **35**.

[0535] Controller **3614** continues to move field of view **3621** from current location **3625** to next location **3624** nearest to maximum **3623** of uncertainty area **3681** from current location **3625** in response to not detecting electromagnetic signals **3603** from electromagnetic signal source **3604**. This type of movement of the field of view **3621** is a nearest to maximum scan **3640**. This scan can be nearest to maximum hexagonal scan **3641** with uncertainty area **3681**.

In this example, uncertainty area **3681** can be in a shape of hexagon **3691**. In other examples, uncertainty area **3681** can be a shape selected from a group comprising a circle, an octagon, an ellipse, or some other suitable shape in addition to or in place of hexagon **3691**.

[0536] Further, controller **3614** can change the manner in which field of view **3621** is moved. In this example, controller **3614** can begin with nearest to maximum scan **3640** and change to nearest neighbor scan **3642**. This type of scan in which the scanning changes from nearest to maximum scan **3640** to nearest neighbor scan **3642** is referred to as hybrid scan **3663**.

[0537] For example, controller **3614** moves field of view **3621** to neighbor location **3643** of nearest neighbor **3644** in response to time **3648** for moving field of view **3621** from current location **3625** to next location **3624** using location **3622** nearest to maximum **3623** of uncertainty area **3681** being greater than threshold **3647**. In this example, next location **3624** becomes current location **3625**.

[0538] Controller **3614** continues to move field of view **3621** from current location **3625** to subsequent neighbor location of nearest neighbor **3644** from current location **325** in response to time **3648** for moving field of view **3621** from current location **3625** to next location **3624** using location **3622** nearest to maximum **3623** of uncertainty area **3681** being greater than threshold **3647** and in response to not detecting electromagnetic signals **3603** from electromagnetic signal source **3604**.

[0539] In this case, threshold **3647** can be selected as the time for moving field of view **3621** from one location to a neighboring location. In another illustrative example, the threshold can be a lower time or some other suitable time.

[0540] Also, moving field of view **3621** to neighbor location **3643** of nearest neighbor **3644** and continuing to move field of view **3621** from current location **3625** to subsequent neighbor location **3645** of nearest neighbor **3644** from current location **3625** is part of nearest neighbor scan **3642** in this example. This nearest neighbor scan can be selected from one of a continuous spiral scan, a step spiral scan, a segmented scan, a hexagonal scan, and a raster scan.

[0541] In this illustrative example, controller **3614** can detect electromagnetic signals **3603** from electromagnetic signal source **3604** in response to detecting selected electromagnetic signals that are greater than a noise level in field of view **3621**. In response to detecting electromagnetic signals **3603**, controller **3614** can establish communications with electromagnetic signal source **3604**. The communications are selected from one of unidirectional communications and bidirectional communications. In the illustrative example, the communications that are unidirectional from electromagnetic signal source **3604** to electromagnetic signal receiver **3602** does not necessarily require electromagnetic signal source **3604** to know that electromagnetic signals **3603** are being received by electromagnetic signal receiver **3602**.

[0542] The illustration of electromagnetic signal environment **3600** in FIG. **36** is not meant to imply physical or architectural limitations to the manner in which an illustrative example may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative example.

[0543] For example, electromagnetic signal receiver system **3601** can be located on a platform. The platform can be a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, a space-based structure, an aircraft, a commercial aircraft, a rotorcraft, a tilt-rotor aircraft, a tilt wing aircraft, a vertical takeoff and landing aircraft, an electrical vertical takeoff and landing vehicle, a personal air vehicle, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a power plant, a bridge, a dam, a house, a manufacturing facility, a building, and other suitable platforms.

[0544] In another illustrative example, controller **3614** can be located in a separate platform or location from electromagnetic signal receiver system **3601**. Additionally, electromagnetic signal receiver system **3601** may be used with an electromagnetic signal transmission system such as electromagnetic beam transmission system **3502** in FIG. **35**.

[0545] In yet another illustrative example, controller **3614** can control one or more electromagnetic signal receiver systems in addition to or in place of electromagnetic signal receiver system **3601**.

[0546] With reference next to FIG. **37**, an illustration of scans performed using scan parameters that are adjusted during the scanning of an uncertainty area is depicted in in accordance with an illustrative embodiment. In this illustrative example, scans **3700** result from applying changes to scan parameters illustrated in spiral scans **3701** to nearest to center scan hexagonal **3702** and hybrid scan **3703**. Nearest to center scan hexagonal **3702** is an example of an implementation for nearest to maximum hexagonal scan **3541** in FIG. **35** in which maximum **3523** of uncertainty area **3581** is the center of uncertainty area **3581**. Hybrid scan **3703** is an example of an implementation for hybrid scan **3563** in FIG. **35**. In this example, hybrid scan **3703** has a hexagonal shape.

[0547] As depicted, spiral scans **3701** include spiral scan **3721**, spiral scan **3722**, and spiral scan **3723**. These spiral scans provide a visual illustration of adjustments to scan parameters that occur during the performance of these spiral scans. In this example, spiral scans **3701** have been selected because the scans provide a clear visualization of changes to scan parameters.

[0548] In this example, these spiral scans include illustrative adjustments to overlap **3711**, beam divergence **3712**, and dwell time **3713**. As depicted, overlap **3711** decreases as spiral scan **3721** progresses. Further in this example, beam divergence **3712** increases as spiral scan **2222** progresses. Further in this example, dwell time **2213** decreases as spiral scan **2223** progresses.

[0549] In this example, nearest to center scan **3731** is nearest to center scan hexagonal **3702** with adjustments to overlap **3711**. In this example, overlap **3711** decreases as nearest to center scan **3731** progresses. Nearest to center scan **3732** is nearest to center scan hexagonal **3702** with adjustments to beam divergence **3712**. In this example, beam divergence **3712** increases as nearest to center scan **3732** progresses. Further, nearest to center scan **3733** is nearest to center scan hexagonal **3702** with adjustments to dwell time **3713**. In this example, dwell time **3713** increases as nearest to center scan **3732** progresses.

[0550] Also in this example, hybrid scan **3734** is hybrid scan **3703** with adjustments to overlap **3711**. As depicted, overlap **3711** decreases as hybrid scan **3703** progresses. Hybrid scan **3736** is hybrid scan **3703** with adjustments to beam divergence **3712**. In this example, beam divergence **3712** increases as hybrid scan **3736** progresses. In this illustrative example, hybrid scan **3736** is hybrid scan **3703** with adjustments to dwell time **3723**. In this example, dwell time **3723** increases as hybrid scan **3736** progresses.

[0551] Turning now to FIG. **38**, an illustration of a nearest to center scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this example, center **3800** of the maximum of the uncertainty area **3801** is scanned using nearest to center scan **3731**. Each circle in FIG. **38** represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3731**.

[0552] Further in this example, uncertainty area **3801** has a circular shape. In this example, nearest to center scan **3731** is a hexagonal scan that scans the area within the circular shape of uncertainty area **3801**. Also, in this illustrative example, nearest to center scan **3731** includes locations that scans regions outside of uncertainty area **3801** to ensure that all of uncertainty area **3801** is scanned in these examples.

[0553] In this example, overlap **3870** for nearest to center scan **3731** decreases as the scan progresses. As depicted, overlap **3870** is greatest near center **3800** and is least at the perimeter of uncertainty area **3801**.

[0554] As depicted, the locations with the same distance from center **3800** form a layer. In this illustrative example, a layer is not necessarily a continuous layer. In other words, the layer can be comprised of segments based on the distance of locations from center **3800**.

[0555] In this example, center **3800** is a first layer that is the innermost layer. A second layer adjacent to center **3800** is formed by location **3851**, location **3852**, location **3853**, location **3854**, location **3855**, and location **3856**. These locations in the second layer all have the same distance from center **3800**.

[0556] A third layer adjacent to the second layer is formed by location **3821**, location **3822**, location **3823**, location **3824**, location **3825**, and location **3826**. These locations in the third layer are all the same distance from center **3800**.

[0557] In this example, overlap **3870** is uniform for locations in nearest to center scan **3731** that have the same distance from center **3800** of the uncertainty area. In other words, overlap **3870** for locations that have the same distance from center **3800** have the same overlap with locations in adjacent layers.

[0558] In these examples, overlap **3870** is between adjacent layers in nearest to center scan **3731**. In other words, an adjacent layer is a layer in which a location in the layer overlaps with a location in another layer that is next to the adjacent layer. This adjacent layer can be a prior layer that has already been scanned or a subsequent layer that will be scanned.

[0559] For example, location **3852** and location **3825** are in adjacent layers to each other. Overlap **3870** between these two locations in the adjacent layers has width **3897**. As another example, location **3831** is in a current layer while location **3832** is in an adjacent layer. In this example, overlap **3870** has width **3871**. Width **3871** is smaller than width **3897**.

[0560] In other words, the overlap **3870** between beam spots moving in nearest to center scan **3731** decreases as the scan progresses. The selection of overlap **3870** can be made in the same manner as overlap **2370** in FIG. **23**.

[0561] Next in FIG. **39**, an illustration of a nearest to center scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this example, center **3900** is the maximum of the uncertainty area **3901** scanned using nearest to center scan **3732**. Each circle in FIG. **39** represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3731**.

[0562] In this depicted example, uncertainty area **3901** has a circular shape. In this example, nearest to center scan **3732** is a hexagonal scan that scans the area within the circular shape of uncertainty area **3901**. Also, in this illustrative example, nearest to center scan **3732** includes locations that scans regions outside of uncertainty area **3801** to ensure that all of uncertainty area **3901** is scanned in these examples.

[0563] In this illustrative example, beam divergence decreases as nearest to center scan **3732** progresses. As depicted, the beam divergence increases during movement of the laser beam to scan uncertainty area **3901**. In this example, the beam divergence at locations that have a same distance from center **3900** in uncertainty area **3901** one is uniform. In other words, the beam divergence is the same for locations with the same distance from center **3900**.

[0564] For example, location **3920** and location **3921** are the same distance from center **3900**. These two locations have the same beam divergence. Location **3922** and location **3923** both have the same distance from center **3900**. These two locations also have the same beam divergence with respect to each other.

[0565] With this example, location **3922** and location **3923** are scanned prior to location **3920** and location **3921**. In this example, location **3920** and location **3921** have larger beam divergence as compared to location **3922** and location **3923**. The selection of beam divergence can be made in the same manner as the selection of beam divergence in FIG. **24**.

[0566] With reference now to FIG. **40**, an illustration of a nearest to center scan with decreasing dwell time is depicted in accordance with an illustrative embodiment. In this illustrative example, center **4000** is the maximum of the uncertainty area **4001** scanned using nearest to center scan **3733**. Each circle in FIG. **40** represents the location of the beam spot for a laser beam that is moved to perform nearest to center scan **3733**.

[0567] In this depicted example, uncertainty area **4001** has a circular shape. In this example, nearest to center scan **3733** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4001**. Also, in this illustrative example, nearest to center scan **3733** includes locations that scans regions outside of uncertainty area **4001** to ensure that all of uncertainty area **4001** is scanned in these examples.

[0568] In this illustrative example, the dwell time decreases as nearest to center scan **3733** progresses. Further, in this example, the dwell time between locations having a same distance from center **4000** is uniform. In other words, these locations have the same dwell time.

[0569] For example, location **4020** and location **4021** are the same distance from center **4000**. These two locations have the same dwell time. Location **4022** and location **4023** have the same distance from center **4000**. These two locations have the same dwell time.

[0570] In this example, location **4020** and location **4021** are scanned later in nearest to center scan **3733** as compared to location **4022** and location **4022**. Location **4020** and location **4021** are farther from center **4000** as compared to these other two locations. As a result, the likelihood that an object of interest is present is lower as compared to location **4022** and location **4023**. Thus, these two locations have a shorter dwell time as compared to location **4022** and location **4023**. The selection of dwell time can be made in the same manner as the selection of dwell time in FIG. **25**.

[0571] In FIG. **41**, an illustration of a hybrid scan with decreasing overlap is depicted in accordance with an illustrative embodiment. In this depicted example, center **4100** is the maximum of the uncertainty area **4101** scanned using hybrid scan **3734**. Each circle in FIG. **41** represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3734**.

[0572] In this depicted example, uncertainty area **4101** has a circular shape. In this example, hybrid scan **3734** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4101**. Also, in this illustrative example, hybrid scan **3734** includes scanning locations that have regions outside of uncertainty area **4101** to ensure that all of uncertainty area **4101** is scanned in these examples.

[0573] In this example, overlap **4170** for hybrid scan **3734** decreases as the scan progresses. As depicted, overlap **4170** is greatest near center **4100** and is least at the perimeter of uncertainty area **4101**.

[0574] In this example, overlap **4170** for locations in hybrid scan **3734** that have the same distance from center **4100** of the uncertainty area is uniform. In other words, the overlap between locations that have the same distance from center **4100** have the same overlap. In other words, overlap **4170** for locations that have the same distance from center **4100** have the same overlap with locations in adjacent layers.

[0575] Locations having the same distance from center **4100** form a layer in this example. For example, location **4120** and location **4122** have the same distance from center **4100** and are part of the same layer. As depicted, location **4123** and location **4124** both have the same distance from center **4100** and thus are part of the same layer. As with the example in FIG. **38**, the overlap is between adjacent layers. The selection of overlap **4170** can be made in the same manner as overlap **2370** in FIG. **23**.

[0576] With reference to FIG. **42**, an illustration of a hybrid scan with increasing beam divergence is depicted in accordance with an illustrative embodiment. In this illustrative example, center **4200** is the maximum of the uncertainty area **4201** scanned using hybrid scan **3735**. Each circle in FIG. **42** represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3735**.

[0577] In this depicted example, uncertainty area **4201** has a circular shape. In this example, hybrid scan **3735** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4201**. Also, in this illustrative example, hybrid scan **3735** includes locations that scans regions outside of uncertainty area **4201** to ensure that all of uncertainty area **4201** is scanned in these examples.

[0578] In this illustrative example, beam divergence decreases as hybrid scan **3735** progresses. As depicted, the beam divergence increases during movement of the laser beam to scan uncertainty area **4201**. In this example, the beam divergence at locations that have a same distance from center **4200** in uncertainty area **4201** is uniform. Thus, the beam divergence is the same for locations with the same distance from center **4100**.

[0579] For example, location **4120** and location **4121** are the same distance from center **4100**. These two locations have the same beam divergence. Location **3922** and location **3923** both have the same distance from center **3900**. These two locations have the same beam divergence with respect to each other.

[0580] With this example, location **4122** and location **4123** are scanned prior to location **4120** and location **4121**. In this example, location **4120** and location **4121** have larger beam divergence as compared to location **3922** and location **3923**. The selection of beam divergence can be made in the same manner as the selection of beam divergence in FIG. **24**.

[0581] With reference now to FIG. **43**, an illustration of a hybrid scan with decreasing dwell time is depicted in accordance with an illustrative embodiment. In this illustrative example, center **4300** is the maximum of the uncertainty area **4301** scanned using hybrid scan **3736**. Each circle in FIG. **43** represents the location of the beam spot for a laser beam that is moved to perform hybrid scan **3735**.

[0582] In this example, uncertainty area **4301** has a circular shape. In this example, hybrid scan **3736** is a hexagonal scan that scans the area within the circular shape of uncertainty area **4301**. Also, in this illustrative example, hybrid scan **3736** includes locations that scans regions outside of uncertainty area **4301** to ensure that all of uncertainty area **4301** is scanned in these examples.

[0583] In this illustrative example, the dwell time decreases as hybrid scan **3736** progresses. Further, in this example, the dwell time between locations having a same distance from center **4300** is uniform. These locations with the same distance have the same dwell time.

[0584] For example, location **4320** and location **4321** are the same distance from center **4300**. These two locations have the same dwell time. Location **4322** and location **4323** have the same distance from center **4300**. Thus, these two locations have the same dwell time.

[0585] In this example, location **4320** and location **4321** are scanned later in hybrid scan **3736** as compared to location **4322** and location **4323**. Location **4320** and location **4321** are farther from center **4300**. As a result, the likelihood that an object of interest is present is lower as compared to location **4022** and location **4023**. Thus, these two locations have a shorter dwell time as compared to location **4022** and location **4023**. The selection of dwell time can be made in the same manner as the selection of dwell time in FIG. **25**.

[0586] The illustration of scans in FIGS. **37-43** has been presented for purposes of depicting an illustrative example. This illustration is not meant to limit the manner in which other illustrative examples can be implemented. For example, the uncertainty areas in these figures have been described as a hexagon. In other illustrative examples, other shapes can be used such as a circle, an octagon, or other shape with a radial symmetry.

[0587] Further, in performing the searches, the nearest to the center scans and hybrid scans can be further optimized in addition to changing a number of scan parameters during the movement of a laser beam. For example, locations in the scan identified as falling outside of the uncertainty area can be skipped.

[0588] Further, in other illustrative examples, other types of electromagnetic beams can be used in addition to the laser beam. For example, the electromagnetic beam used in the scans can be selected from a group comprising a radio frequency beam, a microwave beam, and other suitable types of electromagnetic signals that can be shaped into a beam. Further, these type of scans can also be used in receiving electromagnetic signals from an electromagnetic signal source.

[0589] Turning to FIG. **44**, an illustration of a flowchart of a process for pointing an electromagnetic beam is depicted in accordance with an illustrative embodiment. The process in FIG. **44** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **3514** in computer system **3512** in FIG. **35**.

[0590] The process directs the electromagnetic beam at a location nearest to a maximum of an uncertainty area in which an object is expected to be located (operation **4400**). The process moves the electromagnetic beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the object is at the location, wherein the next location becomes a current location for the electromagnetic beam (operation **4402**).

[0591] The process adjusts a number of scan parameters during a movement of the electromagnetic beam to scan the uncertainty area (operation **4404**). The process continues to move the electromagnetic beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the electromagnetic beam has encountered the object (operation **4406**). The process terminates thereafter.

[0592] With reference next to FIG. **45**, an illustration of a flowchart of a process for pointing a laser beam is depicted in accordance with an illustrative embodiment. The process in FIG. **45** can be implemented in hardware, software, or both. When implemented in software, the process can take the form of program instructions that are run by one of more processor units located in one or more hardware devices in one or more computer systems. For example, the process can be implemented in controller **3514** in computer system **3512** in FIG. **35**.

[0593] The process directs the laser beam at a location nearest to a maximum of an uncertainty area in which a satellite is expected to be located (operation **4500**). In one illustrative example, the uncertainty area is a nearest to maximum hexagonal scan.

[0594] The process moves the laser beam from the location to a next location nearest to the maximum of the uncertainty area in response to not receiving a confirmation that the satellite is at the location, wherein the next location becomes a current location for the laser beam (operation **4502**).

[0595] The process adjusts a number of scan parameters during a movement of the laser beam to scan the uncertainty area (operation **4504**). The process continues to move the laser beam from the current location to the next location nearest to the maximum of the uncertainty area from the current location in response to not receiving the confirmation that the satellite has received the laser beam (operation **4506**). The process terminates thereafter.

[0596] With reference next to FIG. **46**, an illustration of a flowchart of a process for moving the laser beam is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of additional operations that can be performed with operations in FIG. **45**. In this example, the process can move the laser beam to perform a hybrid scan.

[0597] The process moves the laser beam to a neighbor location of a nearest neighbor in response to a time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than a threshold, wherein the next location becomes the current location (operation **4600**). The process continues to move the laser beam from the current location to a subsequent neighbor location of the nearest neighbor from the current location in response to the time for moving the laser beam from the current location to the next location using the location nearest to the maximum of the uncertainty area being greater than the threshold and in response to not receiving the confirmation that the satellite has received the laser beam (operation **4602**). The process terminates thereafter. In this flowchart, operation **4504** from FIG. **45** continues to be performed with these operations to adjust a number of scan parameters.

[0598] With reference now to FIG. **47**, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **4504** in FIG. **45**.

[0599] The process decreases an overlap during the movement of the laser beam to scan the uncertainty area (operation **4700**). The process terminates thereafter. In one illustrative example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the overlap at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0600] Turning to FIG. **48**, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **4504** in FIG. **45**.

[0601] The process increases a beam divergence of the laser beam during the movement of the laser beam to scan the uncertainty area (operation **4800**). The process terminates thereafter. In one illustrative example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the beam divergence of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0602] Next in FIG. **49**, an illustration of a flowchart of a process for adjusting scan parameters is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an implementation for operation **4504** in FIG. **45**.

[0603] The process decreases a dwell time for the laser beam during movement of the laser beam to scan the uncertainty area (operation **4900**). The process terminates thereafter. In this example, the maximum of the uncertainty area is a center of an uncertainty area and wherein the dwell time of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

[0604] With reference now to FIG. **50**, an illustration of a flowchart of a process for establishing communications is depicted in accordance with an illustrative embodiment. The process in this flowchart is an example of an additional operation that can be performed with the operations in FIG. **45**.

[0605] The process establishes communications with the satellite in response to receiving the confirmation (operation **5000**). The process terminates thereafter.

[0606] The flowcharts and block diagrams in the different depicted embodiments in FIGS. **44-50** illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams can represent at least one of a module, a segment, a function, or a portion of an operation or step. For example, one or more of the blocks can be implemented as program instructions, hardware, or a combination of the program instructions and hardware. When implemented in hardware, the hardware can, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program instructions and hardware, the implementation may take the form of firmware. Each block in the flowcharts or the block diagrams can be implemented using special purpose hardware systems that perform the different operations or combinations of special purpose hardware and program instructions run by the special purpose hardware.

[0607] In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be performed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

[0608] The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the embodiments in the form disclosed. The different illustrative examples describe components that perform actions or operations. In an illustrative embodiment, a component can be configured to perform the action or operation described. For example, the component can have a configuration or design for a structure that provides the component an ability to perform the action or operation that is described in the illustrative examples as being performed by the component. Further, to the extent that terms "includes", "including", "has", "contains", and variants thereof are used herein, such terms are intended to be inclusive in a manner similar to the term "comprises" as an open transition word without precluding any additional or other elements.

[0609] Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A laser beam transmission system comprising:

a laser beam system configured to transmit a laser beam; and

a controller configured to control the laser beam system to:

direct the laser beam at a 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;

adjust a number of scan parameters during a movement of the laser beam to scan the uncertainty area; 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 in adjusting the number of scan parameters, the controller is configured to:

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

3. The laser beam transmission system of claim **2**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the overlap at locations that have a same distance from the maximum of the uncertainty area is uniform.

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

increase a beam divergence of the laser beam during the movement of the laser beam to scan the uncertainty area.

5. The laser beam transmission system of claim **4**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the beam divergence of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

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

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

7. The laser beam transmission system of claim **6**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the dwell time of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

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

9. 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.

10. The laser beam transmission system of claim **9**, 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, a hexagonal scan, and a raster scan.

11. 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.

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

13. An electromagnetic beam transmission system comprising:

an electromagnetic beam system configured to transmit an electromagnetic beam; and

a controller configured to control the electromagnetic beam 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;

adjust a number of scan parameters during a movement of the electromagnetic beam to scan the uncertainty area; 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.

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

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

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

directing the laser beam at a 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;

adjusting a number of scan parameters during a movement of the laser beam to scan the uncertainty area; 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.

17. The method of claim **16**, wherein a movement of the laser beam to scan the uncertainty area is in a form of a nearest to maximum hexagonal scan.

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

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

20. The method of claim **19**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the overlap at locations that have a same distance from the maximum of the uncertainty area is uniform.

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

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

22. The method of claim **21**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the beam divergence of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

23. The method of claim **18**, wherein adjusting the number of scan parameters comprises:

decreasing a dwell time for the laser beam during movement of the laser beam to scan the uncertainty area.

24. The method of claim **23**, wherein the maximum of the uncertainty area is a center of an uncertainty area and wherein the dwell time of the laser beam at locations that have a same distance from the maximum of the uncertainty area is uniform.

25. The method of claim **16** further comprising:

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

26. The method of claim **16**, wherein the number of scan parameters is selected from at least one of an overlap, a beam divergence, or a dwell time.

27. 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;

adjusting a number of scan parameters during a movement of the electromagnetic beam to scan the uncertainty area; 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.

28. The method of claim **27**, wherein the number of scan parameters is selected from at least one of an overlap, a beam divergence, or a dwell time.

29. An electromagnetic signal receiver system comprising:

an electromagnetic signal receiver configured to receive electromagnetic signals; and

a controller configured to control the electromagnetic signal receiver to:

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

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 electromagnetic signals from the electromagnetic signal source at the location, wherein the next location becomes a current location for the field of view;

adjust a number of scan parameters during a movement of the field of view to scan the uncertainty area; and

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 electromagnetic signals from the electromagnetic signal source.

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