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Miller

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(54) **ELECTROMAGNETIC RADIATION SOURCE LOCATING SYSTEM**

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(73) Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, DC (US)

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G01S 19/18	(2010.01)

(52) **U.S. Cl.** **342/465**; 342/357.34; 342/357.55; 342/357.56

(58) **Field of Classification Search** 342/465, 342/359, 357.55, 357.56, 357.52, 357.34
See application file for complete search history.

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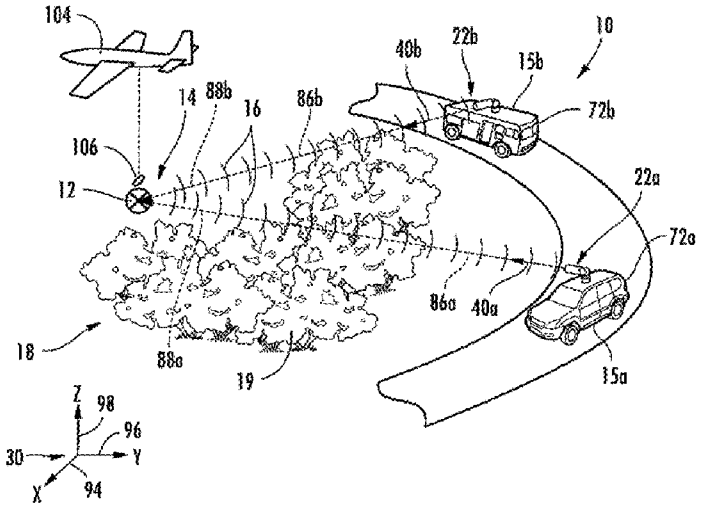
(57) **ABSTRACT**

An electromagnetic radiation source locating system including an electromagnetic radiation sensor including an antenna configured to detect a radiant energy transmission. A position detector is in communication with the controller and is configured to detect the position of the antenna relative to a reference coordinate system, while an orientation sensor is in communication with the controller and is configured to detect the orientation of the antenna and provide an orientation signal to the controller. A range sensor is configured to detect the distance to an aligned object in the path of a directional vector and provide a distance signal indicative thereof to the controller. An aerial vehicle may be in communication with the controller and configured to drop a marker for guiding navigators to the source of the radiant energy transmission.

10 Claims, 8 Drawing Sheets



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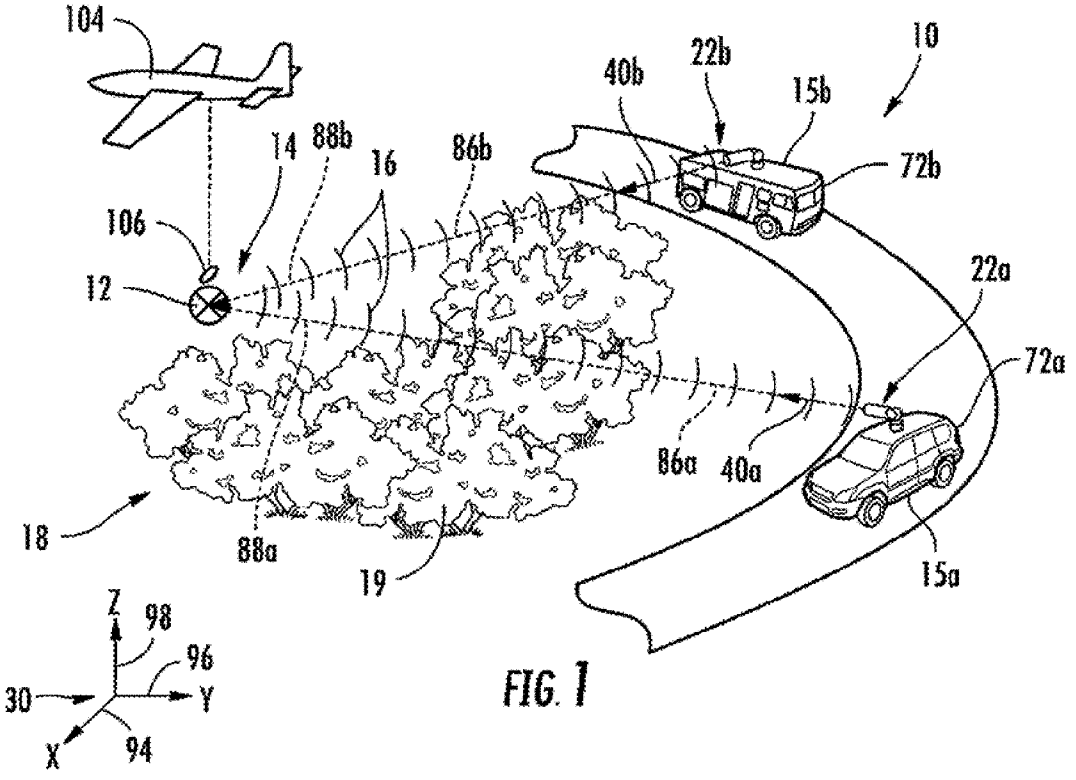
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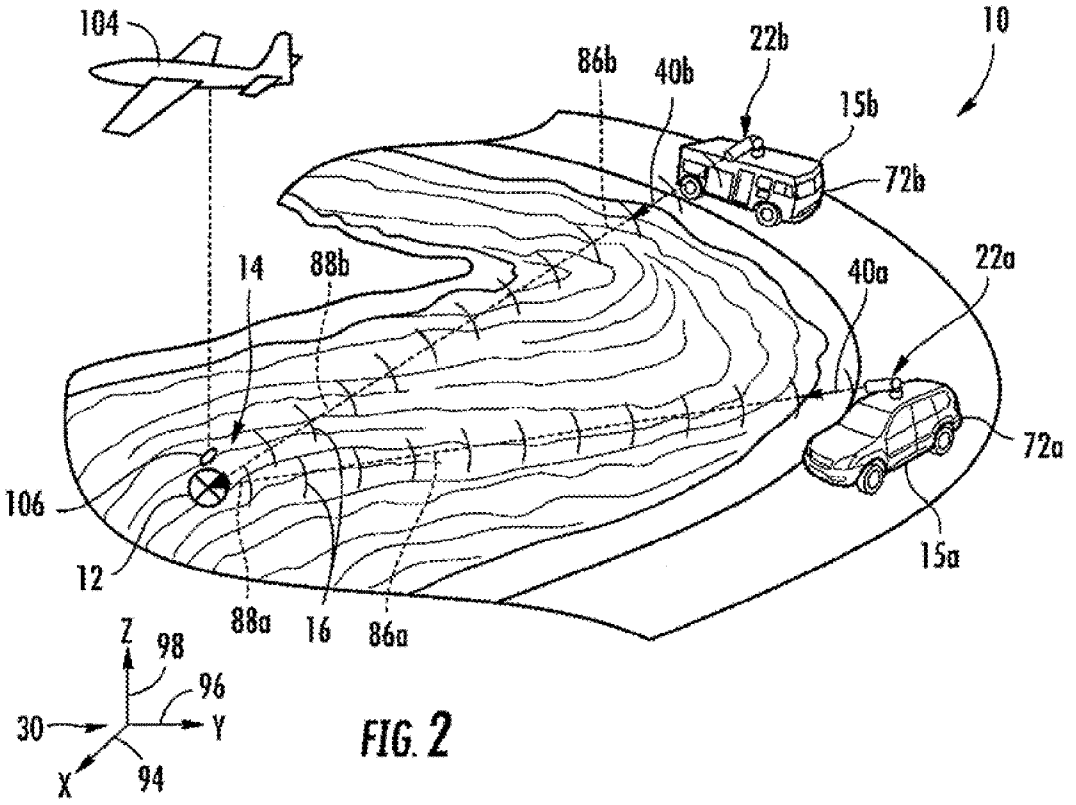
10
40b
22b
15b
14
88b
16
86b
72b
106
12
22a
72a
86a
40a
18
88a
19
15a
Z
98
96
30
Y
X
94

FIG. 1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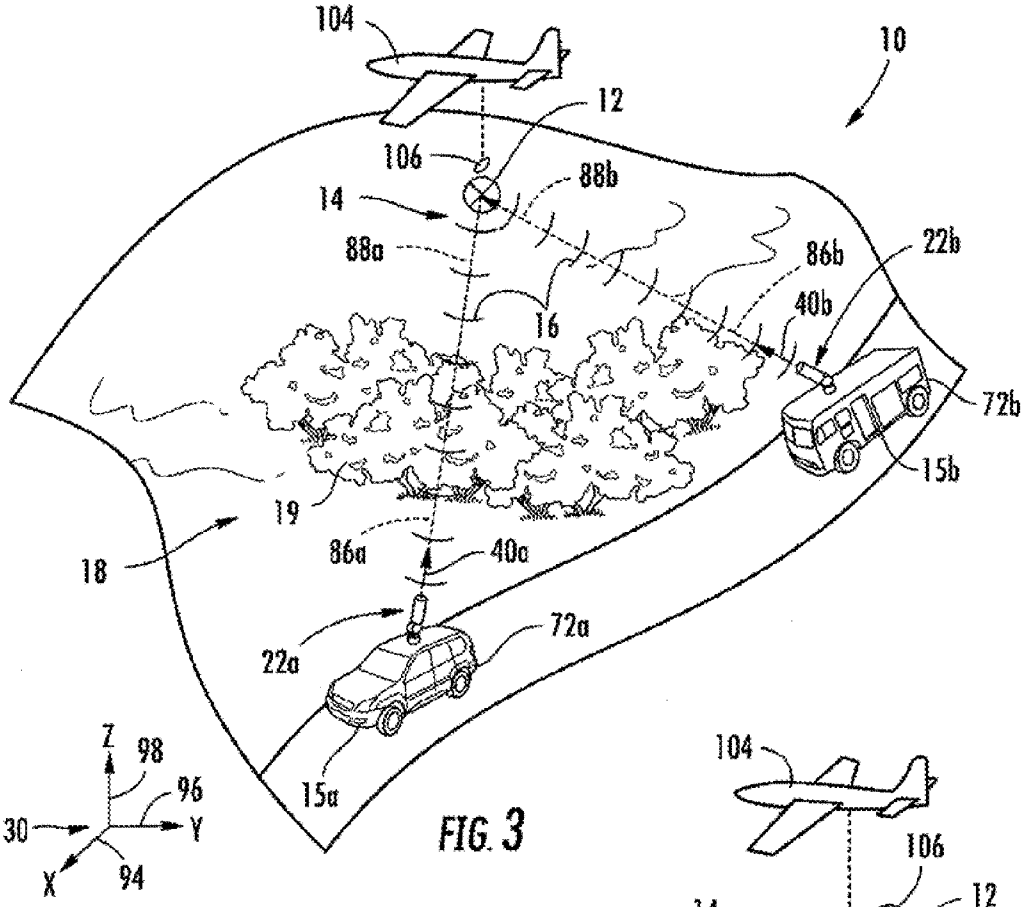
10
86b
40b
22b
15b
72b
14
88b
40a
22a
72a
106
12
15a
88a
16
86a
Z
98
96
30
Y
X
94

FIG. 2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10
12
106
14
88b
88a
86b
22b
40b
16
72b
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19
18
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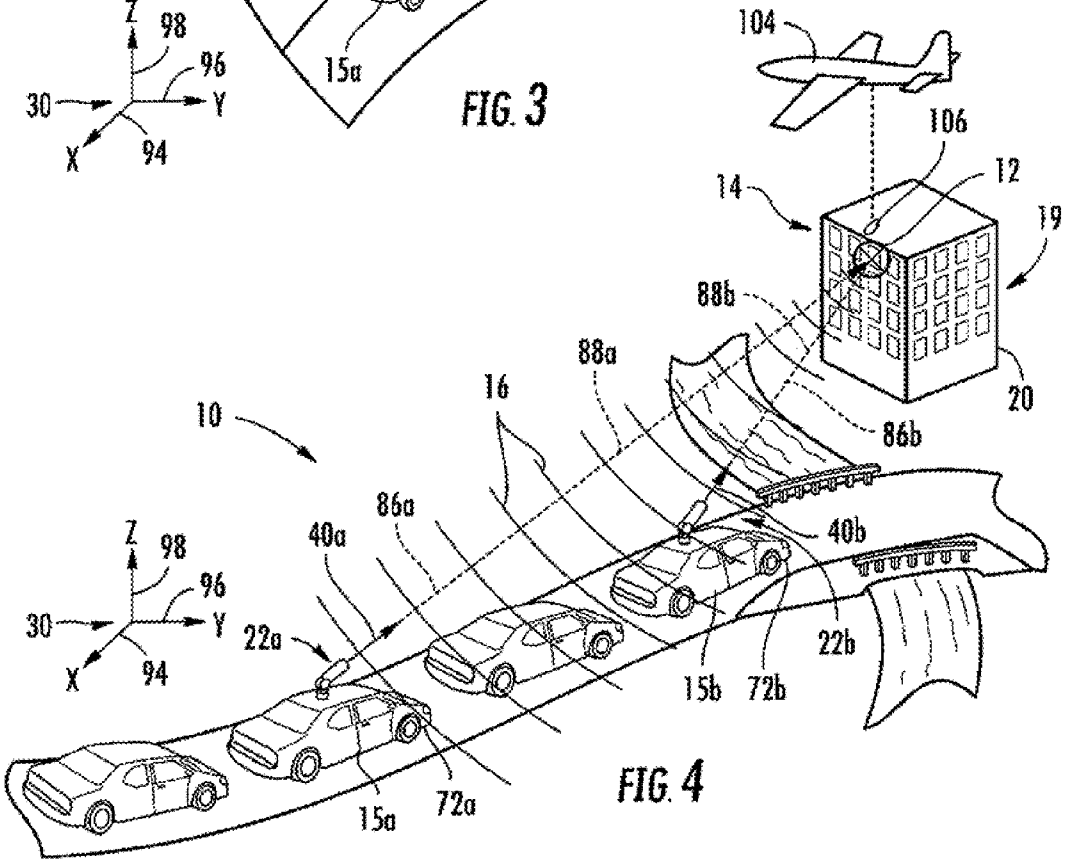
98
96
30
Y
X
94

FIG. 3


104
106
12
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88b
88a
20
16
10
86b
86a
40a
40b
Z
98
96
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Y
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X
94
15b
72b
15a
72a

FIG. 4

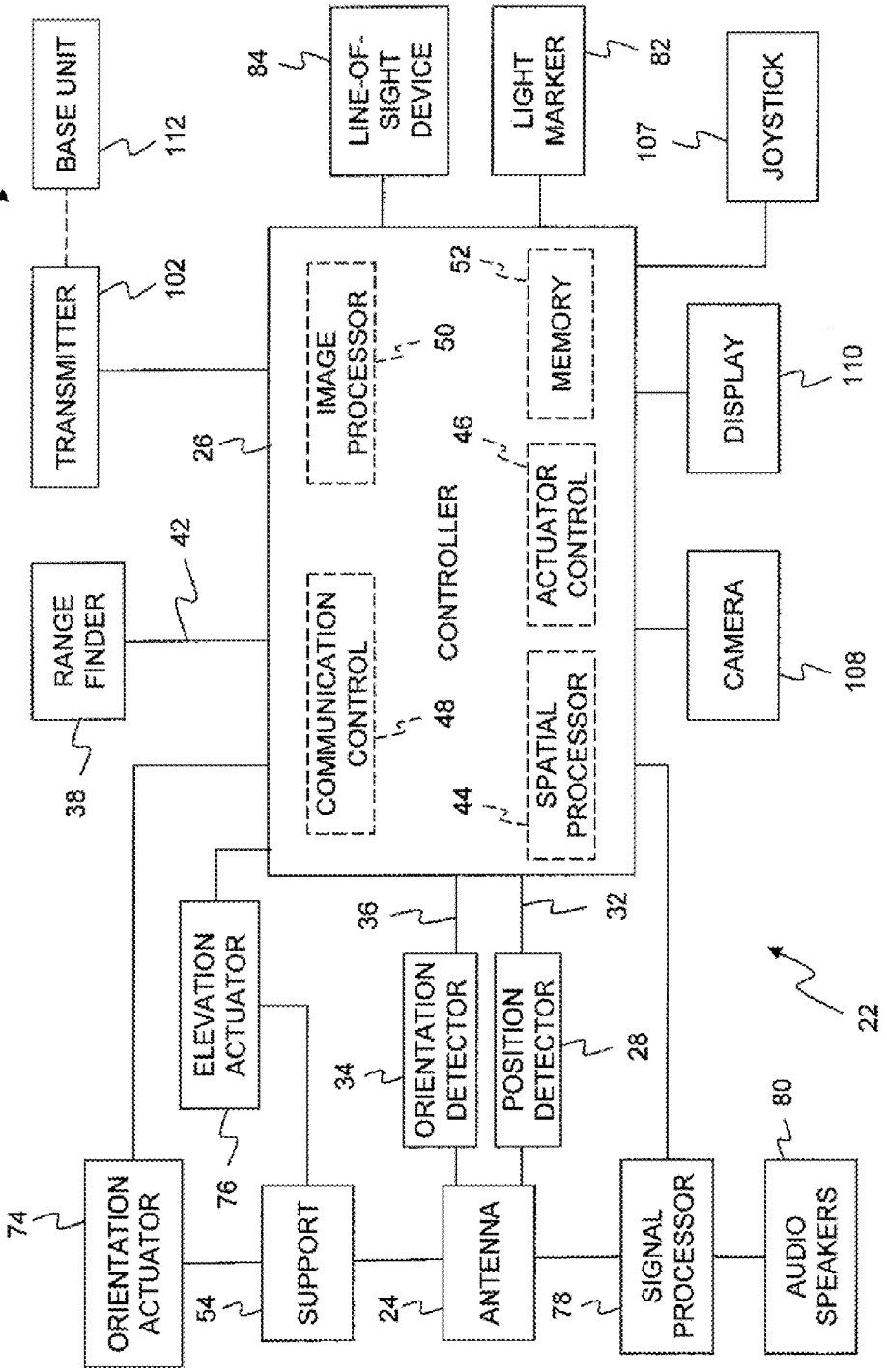
10
BASE UNIT
112
TRANSMITTER
102
RANGE FINDER
38
42
26
CONTROLLER
IMAGE PROCESSOR
50
COMMUNICATION CONTROL
48
SPATIAL PROCESSOR
44
ACTUATOR CONTROL
46
MEMORY
52
LINE-OF-SIGHT DEVICE
84
LIGHT MARKER
82
JOYSTICK
107
DISPLAY
110
CAMERA
108
22
ELEVATION ACTUATOR
76
ORIENTATION DETECTOR
34
POSITION DETECTOR
28
36
32
ORIENTATION ACTUATOR
74
54
SUPPORT
24
ANTENNA
78
SIGNAL PROCESSOR
AUDIO SPEAKERS
80

FIG. 5

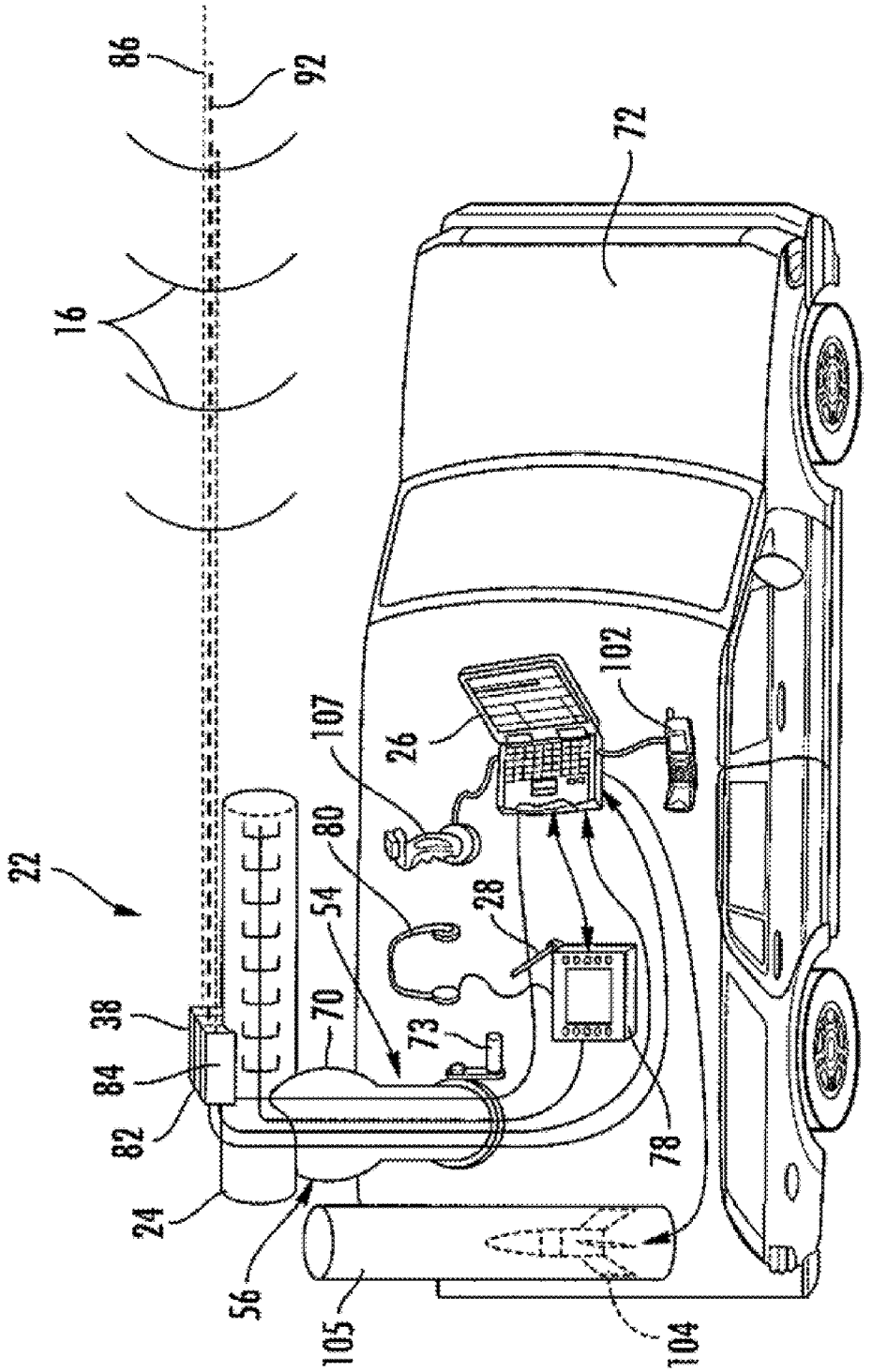

FIG. 6

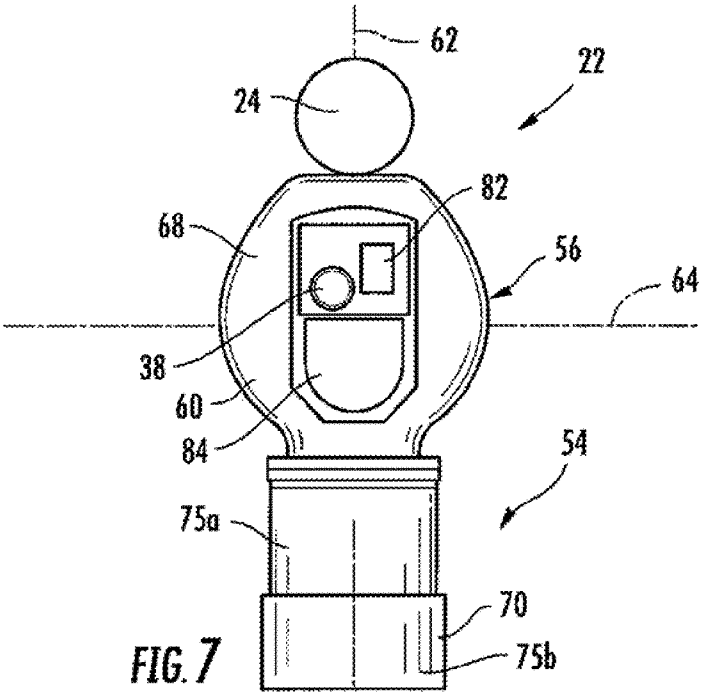
62
22
24
82
68
56
64
38
60
84
54
75a
70
75b

FIG. 7

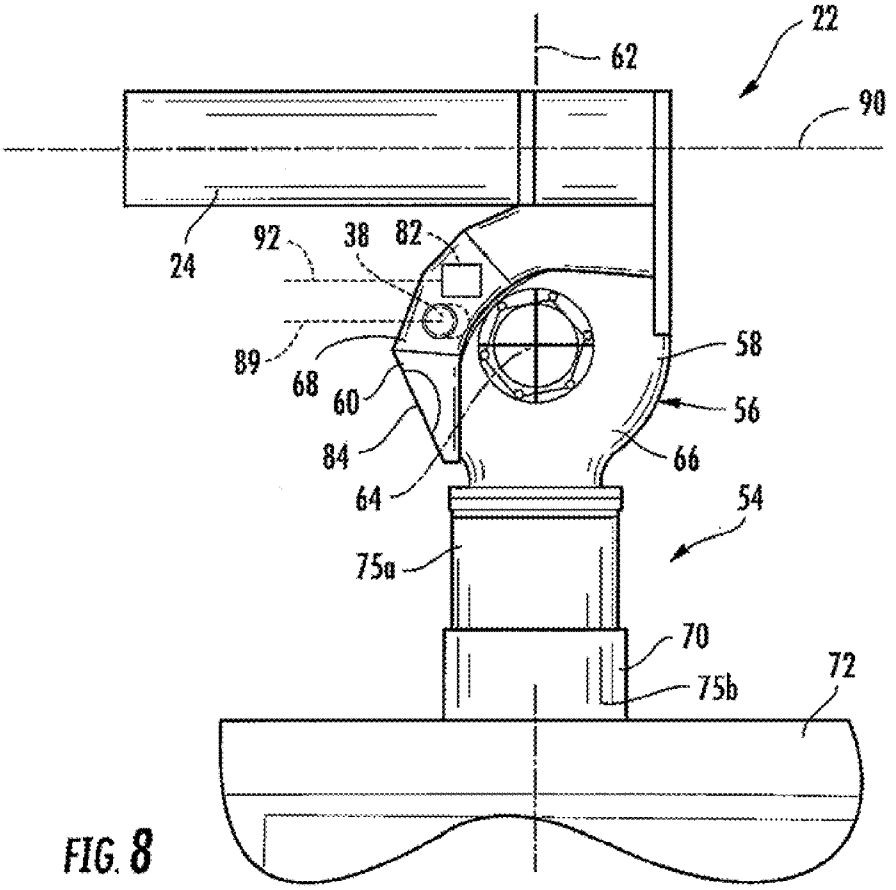
22
62
90
24
92
38
82
89
68
60
58
56
84
66
64
54
75a
70
75b
72

FIG. 8

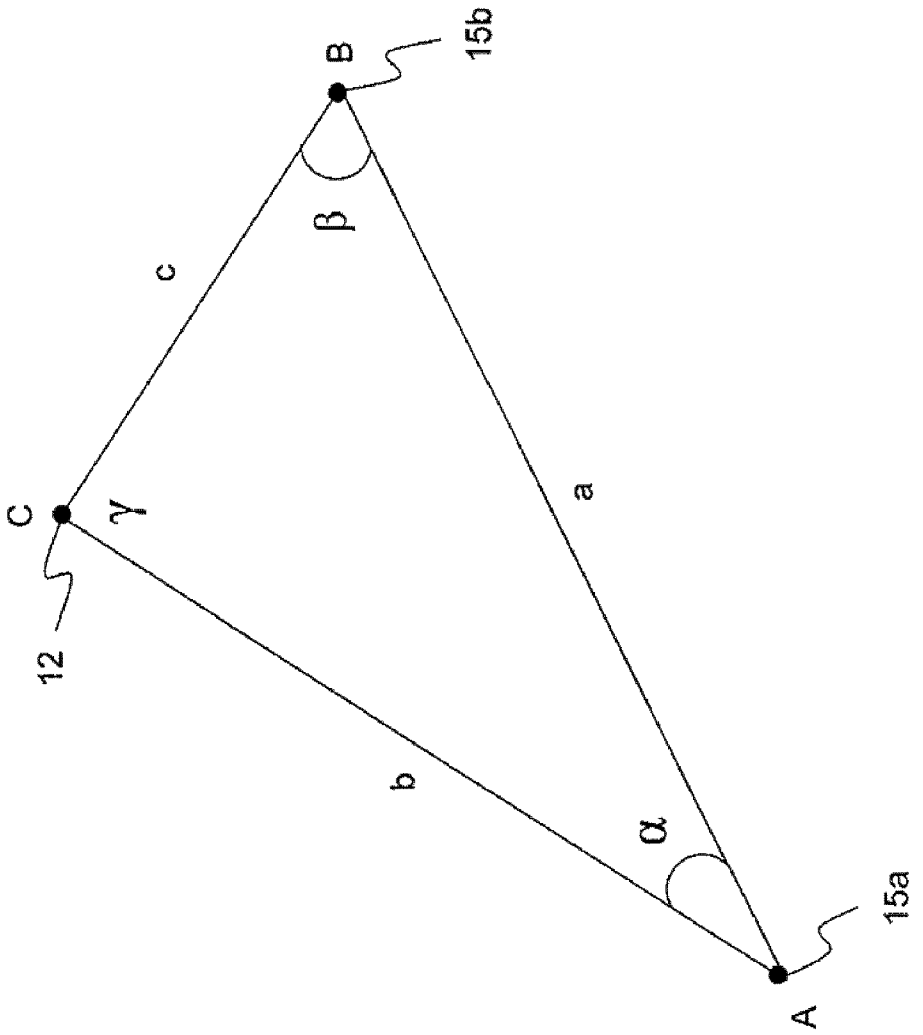

FIG. 9

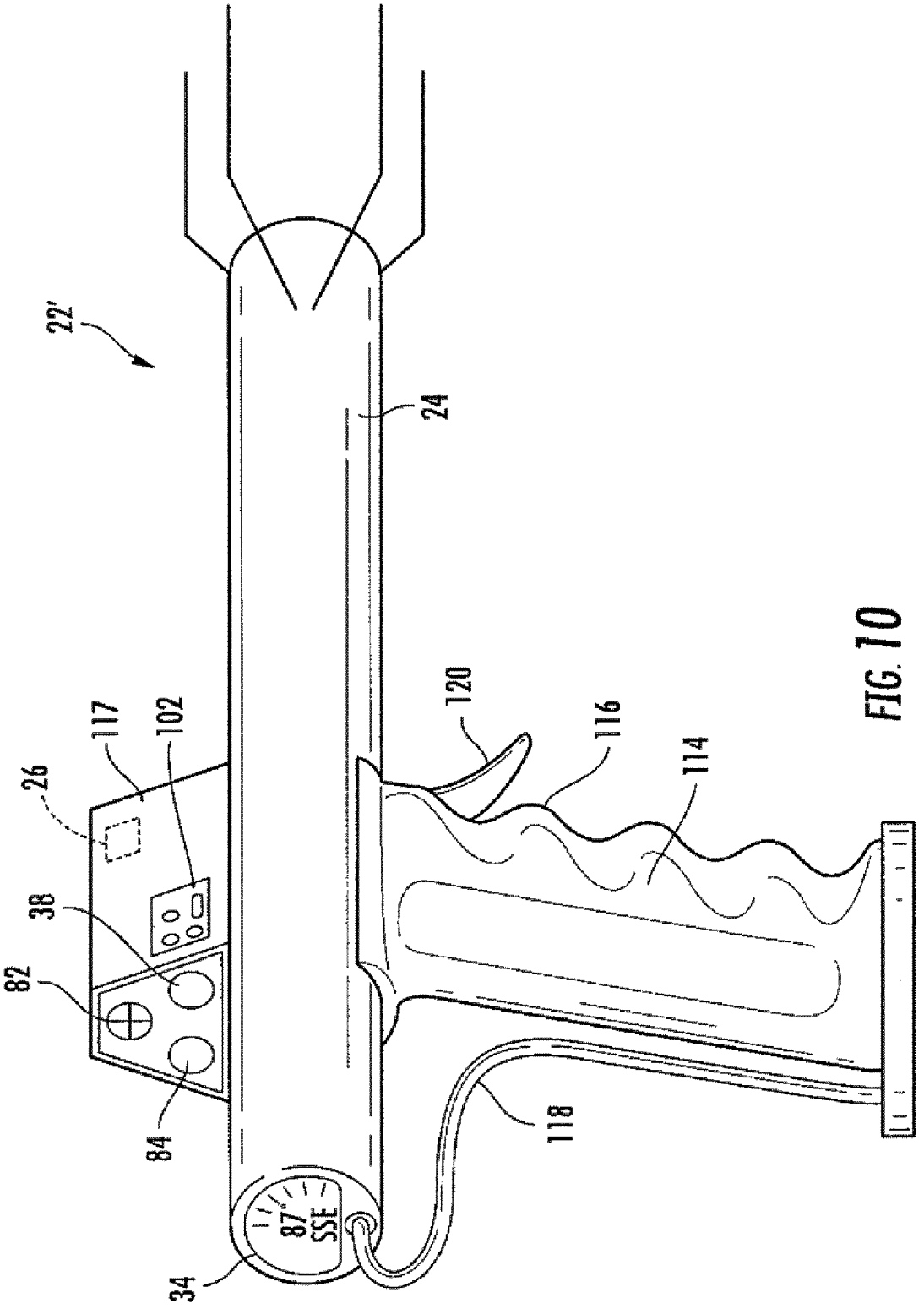

FIG. 10

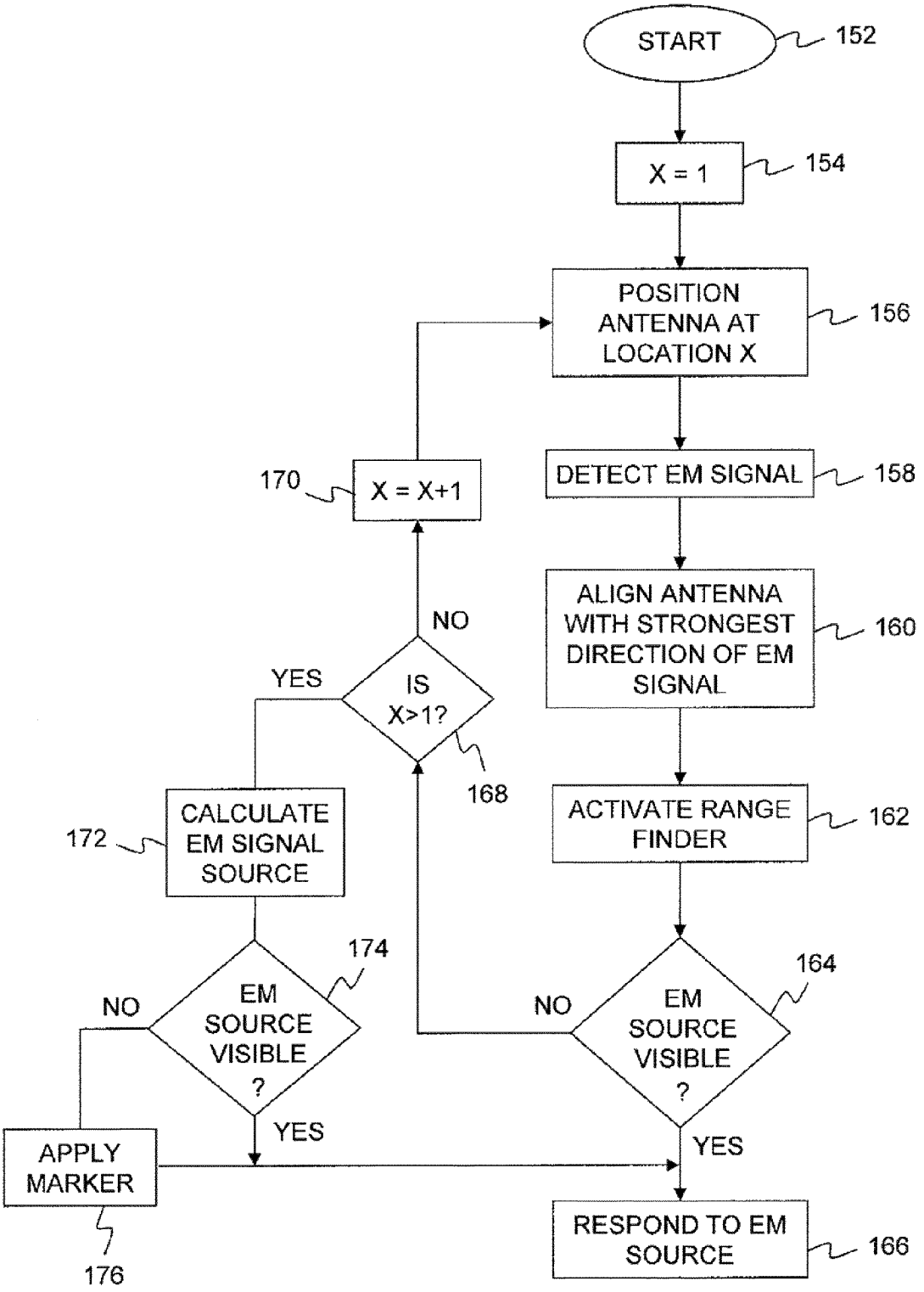
START
152
X = 1
154
POSITION ANTENNA AT LOCATION X
156
DETECT EM SIGNAL
158
ALIGN ANTENNA WITH STRONGEST DIRECTION OF EM SIGNAL
160
ACTIVATE RANGE FINDER
162
EM SOURCE VISIBLE ?
164
NO
YES
RESPOND TO EM SOURCE
166
IS X>1?
168
NO
YES
X = X+1
170
CALCULATE EM SIGNAL SOURCE
172
EM SOURCE VISIBLE ?
174
NO
YES
APPLY MARKER
176

FIG. 11

ELECTROMAGNETIC RADIATION SOURCE LOCATING SYSTEM

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

The invention described herein was made in the performance of official duties by an employee of the Department of the Navy and may be manufactured, used and licensed by or for the United States Government for any governmental purpose without payment of any royalties thereon.

BACKGROUND OF THE INVENTION

The present invention relates generally to systems for locating electromagnetic radiation sources, such as radio frequency (RF) signal sources.

Radio frequency detectors are known in the art for passively detecting radio frequency signal sources. For instance, radio frequency signal hunters exist for detecting signal sources based upon detected signal strength. Radio frequency interferometers have also been used to receive RF signals on a linear array of sensors in order to calculate a spatial relationship between the array sensors and the source of RF energy.

However, the need exists for an efficient, comprehensive, and dependable locating system to clearly locate, identify, and mark an RF signal source. Exemplary applications of such a locating system include identifying rogue or interfering RF signal sources, and tracking down RF signal sources, such as cellular phone signals. Such a locating system may find particular use in a variety of circumstances, for example, in the telecommunication industry for locating RF signal sources interfering with cellular phone towers. Such a locating system may also find use by rescue personnel to track down a user in distress, for example, an individual involved in an automobile crash in a remote area or lost in a sparsely inhabited area where cell towers are far between, and target signals may be weak or masked.

SUMMARY OF THE INVENTION

According to an illustrative embodiment of the present disclosure, an electromagnetic radiation source locating system includes an electromagnetic radiation sensor having an antenna configured to detect a radiant energy transmission. A controller is in communication with the electromagnetic radiation sensor. A support is operably coupled to the electromagnetic radiation sensor for supporting the antenna in a plurality of orientations relative to the radiant energy transmission. A position detector is in communication with the controller, and is configured to detect the translational position of the antenna relative to a reference coordinate system and provide a position signal indicative thereof to the controller. An orientation detector is in communication with the controller, and is configured to detect the rotational orientation of the antenna and provide an orientation signal indicative thereof to the controller. The controller is configured to determine a directional vector to a source of the radiant energy transmission in response to the orientation signal. A range sensor is in communication with the controller, and is configured to detect a distance to an aligned object in the path of the directional vector and provide a distance signal indicative thereof to the controller.

According to another illustrative embodiment of the present disclosure, a radio frequency source locating system includes a directional antenna configured to receive radio frequency signals. A radio frequency signal processor is operably coupled to the antenna. A support is configured to be mounted to a vehicle and is operably coupled to the antenna. An actuator is configured to rotate the directional antenna about at least two perpendicular axes. A controller is in communication with the radio frequency signal processor and is configured to cause the actuator to orient the antenna in a direction based upon the strength of the radio frequency signals. A position detector is in communication with the controller, and is configured to detect the translational position of the directional antenna relative to a reference coordinate system and to provide a position signal indicative thereof to the controller. An orientation detector is in communication with the controller, and is configured to detect the rotational orientation of the directional antenna and provide an orientation signal indicative thereof to the controller. The controller is configured to determine a directional vector to a source of the radio frequency signals in response to the orientation signal.

According to a further illustrative embodiment of the present disclosure, an electromagnetic radiation source locating system includes an electromagnetic radiation sensor having a collector configured to detect a radiant energy transmission. A controller is in communication with the electromagnetic radiation sensor. A support is operably coupled to the electromagnetic radiation sensor and is configured to orient the collector of the electromagnetic radiation sensor in a direction toward the strongest radiant energy transmission detected by the collector. A position detector is in communication with the controller, and is configured to detect the translational position of the collector of the electromagnetic radiation sensor relative to a reference coordinate system and provide a position signal indicative thereof to the controller. An orientation detector is in communication with the controller and is configured to detect the rotational orientation of the collector of the electromagnetic radiation sensor and provide an orientation signal indicative thereof to the controller. The controller is configured to determine a directional vector to a source of the radiant energy transmission in response to the orientation signal. The controller includes a spatial processor configured to calculate the location of the radiant energy transmission source based upon at least two different directional vectors. An aerial vehicle is in communication with the controller, and a marker is configured to be dropped by the aerial vehicle on the calculated location of the radiant energy transmission source.

According to yet another illustrative embodiment of the present disclosure, an electromagnetic radiation source locating system includes a first vehicle, a first electromagnetic radiation receiving device supported by the first vehicle and configured to detect a radiant energy transmission. A first directional antenna is operably coupled to the receiving device. A first support is operably coupled to the first electromagnetic radiation receiving device for orienting the first directional antenna in a direction toward the radiant energy transmission. A first position detector is in communication with the controller and is configured to detect the position of the first directional antenna relative to a reference coordinate system. A first orientation detector is in communication with the controller and configured to detect the orientation of the first directional antenna and provide a directional signal indicative thereof to the controller. The electromagnetic radiation source locating system further includes a second vehicle, and a second electromagnetic radiation receiving device supported by the second vehicle and configured to detect a radiant energy transmission. A second directional antenna is operably coupled to the receiving device. A second support is operably coupled to the second electromagnetic

radiation receiving device for orienting the second directional antenna in a direction toward the radiant energy transmission. A second position detector is configured to detect the position of the second directional antenna relative to the reference coordinate system. A second direction detector is in communication with the controller and is configured to detect the orientation of the second directional antenna and provide a directional signal indicative thereof to the controller. A controller is configured to determine a directional vector to the radiant energy transmission source. The controller includes a spatial processor configured to calculate the location of the radiant energy transmission source based upon at least two different directional vectors.

According to a further illustrative embodiment of the present disclosure, a method of detecting a transmission source of electromagnetic radiation, includes the steps of positioning a directional antenna at a first location, detecting an electromagnetic signal at the first location with the directional antenna, and aligning the directional antenna at the first location based upon the strength of the detected electromagnetic radiation signal. The method further includes the steps of directing a light source from the first location in the direction of the aligned directional antenna, positioning a directional antenna at a second location, and detecting an electromagnetic signal at the second location with the directional antenna. The method further includes the steps of aligning the directional antenna at the second location with based upon the strength of the detected electromagnetic radiation signal, and directing a light source from the second location in the direction of the aligned directional antenna. The method further includes the steps of calculating the expected intersection point of the light source from the first location and the light source from the second location.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same become better understood by reference to the following detailed description when taken in conjunction with the accompanying drawings.

FIG. **1** is a diagrammatic view showing an illustrative embodiment electromagnetic radiation source locating system for locating a transmission source at least partially hidden by an obstruction;

FIG. **2** is a diagrammatic view similar to FIG. **1**, showing a transmission source at an elevation below the electromagnetic radiation source locating system;

FIG. **3** is a diagrammatic view similar to FIG. **1**, showing a transmission source at an elevation above the electromagnetic radiation source locating system and at least partially hidden by an obstruction;

FIG. **4** is a diagrammatic view showing an illustrative electromagnetic radiation source locating system for locating a transmission source positioned within a structure;

FIG. **5** is a block diagram illustrating communication between various components of the illustrative electromagnetic radiation source locating system;

FIG. **6** is a perspective view, in partial schematic, of the illustrative electromagnetic radiation source locating system of FIG. **5** supported within a vehicle;

FIG. **7** is a front view of an illustrative sensor assembly of the electromagnetic radiation source locating system as coupled to a vehicle;

FIG. **8** is a side elevational view of the illustrative sensor assembly of FIG. **7**;

FIG. **9** is a diagrammatic view demonstrating illustrative calculations used by the spatial processor of the controller of the electromagnetic radiation source locating system;

FIG. **10** is an illustrative hand held embodiment of the electromagnetic radiation source locating system; and

FIG. **11** flowchart showing an illustrative method of operation of the electromagnetic radiation source locating system.

Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent embodiments of various features and components according to the present disclosure, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present disclosure. The exemplification set out herein illustrates embodiments of the invention, and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE DRAWINGS

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings, which are described below. The embodiments disclosed below are not intended to be exhaustive or limit the invention to the precise form disclosed in the following detailed description. Rather, the embodiments are chosen and described so that others skilled in the art may utilize their teachings. It will be understood that no limitation of the scope of the invention is thereby intended. The invention includes any alterations and further modifications in the illustrated devices and described methods and further applications of the principles of the invention which would normally occur to one skilled in the art to which the invention relates.

With reference initially to FIGS. **1-4**, the electromagnetic radiation source locating system **10** of the present disclosure is configured to detect, categorize, and locate the source **12** of a radiant energy transmission **14** from at least one data acquisition location **15**. As used within the following description, each data acquisition location will be identified with the reference number **15** followed by a letter (i.e., **15***a*, **15***b*, etc.). Also, as used herein, electromagnetic radiation is considered to be made up of oscillating electric and magnetic fields, is propagated with the speed of light, and includes gamma radiation, X-rays, ultraviolet, visible, and infrared radiation, and radar and radio waves. In the illustrative embodiment, the electromagnetic radiation source **12** illustratively comprises a radio frequency transmitter, such as a two-way radio or cellular telephone, emitting a radio frequency (RF) signal **16**. As known, radio frequency waves are generally considered to be within a frequency range from about 3 kHz to about 300,000 MHz. However, it should be appreciate that the system **10** of the present invention is not limited to such a range of the electromagnetic spectrum and may be used to detect other sources of electromagnetic radiation.

As further detailed herein, FIG. **1** illustrates the use of the locating system **10** wherein an obstruction **18** (in the form of a wooded area **19**) exists intermediate the locating system **10** and the signal transmission source **12**. More particularly, the wooded area **19** at least partially obstructs the view of the electromagnetic radiation source **12** from the data acquisition locations **15***a* and **15***b*. FIG. **2** shows the electromagnetic radiation source **12** at a lower elevation than the locating system **10**, while FIG. **3** shows the electromagnetic radiation source **12** at a higher elevation than the locating system **10**.

FIG. **4** illustrates the combination of different elevations between the signal transmission source **12** and the locating system **10** and an obstruction **18** (in the form of a building **20**) positioned therebetween.

According to the illustrative embodiment of FIGS. **5** and **6**, the electromagnetic radiation source locating system **10** includes an electromagnetic radiation sensor assembly **22** including an antenna **24** configured to detect radiant energy transmission **14**, illustratively RF signal **16**. A controller **26** is in communication with the electromagnetic radiation sensor assembly **22**.

The electromagnetic radiation sensor assembly **22** further includes a position detector **28** in communication with the controller **26** and configured to detect the translational position of the antenna **24** relative to a reference coordinate system **30** (FIGS. **1-4**) and provide a position signal **32** indicative thereof to the controller **26**. An orientation detector **34** is also in communication with the controller **26** and is configured to detect the rotational orientation of the antenna **24** and provide an orientation signal **36** indicative thereof to the controller **26**. A range sensor or finder **38** is in communication with the controller **26** and is configured to detect the distance to an aligned object in the path of a directional vector **40** calculated by the controller **26** and to provide a distance signal **42** indicative thereof to the controller **26**.

The controller **26** may include a variety of processors or computing elements configured to manipulate input and produce a desired output. As further detailed herein, these various processors may include a spatial processor **44**, an actuator control **46**, a communication control **48**, and an image processor **50**. The controller **26** may also include a memory **52** for storing various data for subsequent manipulation by the various processors. In certain illustrative embodiments, the controller **26** may comprise a mobile or laptop computer.

The antenna **24** of the illustrative system comprises a directional or beam antenna. As is known, a directional antenna focuses RF energy in a particular direction providing for increases performance in transmitting and receiving, and reducing interference from unwanted signal sources. In the illustrative embodiment, the antenna **24** comprises a Yagi antenna including an array of a dipole and additional closely coupled parasitic elements, usually a reflector and one or more directors (not shown).

The antenna **24** is illustrative operably coupled to a support **54**. As shown in FIGS. **7** and **8**, the support **54** may include a spherical member or ball turret **56** including a pair of gimbals **58** and **60**. The gimbals **58** and **60** provide for rotation of the spherical member **56** about two perpendicular axes **62** and **64**. More particularly, gimbal **58** includes a base portion **66** configured to rotate about a substantially vertical axis **62**. Gimbal **60** includes a cap portion **68** supported by the base portion **66** configured to rotate about a substantially horizontal axis **64**.

The base portion **66** of spherical member **56** is illustratively rotatably coupled to a mast **70** which, in turn, is coupled to a vehicle **72**. An orientation actuator **74** (FIG. **5**) is operably coupled to the spherical member **56** and is configured to cause rotation thereof, and hence of the antenna **24**, about the axes **62** and **64**. The actuator control **46** of the controller **26** is in communication with the orientation actuator **74** for controlling movement thereof. The orientation actuator **74** may be of conventional design, such as a pair of electric servo-motors or hydraulic rotary motors (not shown). A manual input **73**, such as a hand crank, may be provided as an override to the orientation actuator **74**. Illustratively, the manual input **73** may be used to fine tune to positioning of the antenna **24** following adjustment by the actuator **74**, for example to align the antenna **24** in the direction of the strongest detected signal **16**.

In one illustrative embodiment, the mast **70** may be raised or lowered by an elevation actuator **76** (FIG. **5**), illustratively an electric motor coupled to a rack and pinion, or a hydraulic cylinder (not shown). As shown in FIGS. **7** and **8**, the mast **70** may be formed of telescoping members **75***a* and **75***b* to provide a compact arrangement when in a lowered position. The actuator control **46** of the controller **26** is in communication with the elevation actuator **76** for controlling operation thereof.

With further reference to FIGS. **1** and **5**, the antenna **24** is in communication with a signal processor **78**. The signal processor **78** may be separate from or integrated with the controller **26** and is configured to analyze, interpret, and manipulate the detected RF signals **16**. Processing of the RF signals **16** may include filtering, storage and reconstruction, separation of information from noise, and feature extraction. In one illustrative embodiment, the signal processor **78** identifies and classifies the detected RF signals **16**. More particularly, the signal processor **78** may be utilized by the controller **26** to determine the relative strengths of signals **16** based upon different orientations of the antenna **24**. In one illustrative embodiment, an audio speaker **80**, such as headphones, may be provided to generate an audible signal to the user that varies depending upon the strength of the detected signal **16**. One illustrative signal processor **78** that may be used with the locating system **10** is the H600 RFHawk Signal Hunter available from Tektronix Communications of Richardson, Tex.

The cap portion **68** of spherical member **56** may also support range finder **38**, a light marker **82**, and a line-of-sight device **84**. Illustratively, the range finder **38** is in communication with the controller **26** and is configured to measure distance from the observer to a target. The range finder **38** may be a laser range finder configured to transmit a laser pulse **86** and determine distance to an aligned object based upon the return pulse **88** as reflected off the aligned object (which could be an obstruction **18**, such as woods **19** in FIGS. **1** and **3**). In one illustrative embodiment, the longitudinal axis **89** of the laser range finder **38** extends parallel to the longitudinal axis **90** of the antenna **24** such that the laser pulse **86** is coaxial therewith.

The light marker **82** may also include a laser configured to transmit an infrared beam **92** (FIGS. **6** and **8**) parallel to the longitudinal axis **90** of the antenna **24**. As such, the beam **92** may be used to mark a target aligned with the antenna **24**. The light marker **82** is illustratively night vision goggle (NVG) capable for viewing in dark or low light conditions with proper night vision equipment. More particularly, the line-of-sight device **84** may be night vision capable and illustratively comprises an infrared spotting scope configured to detect the infrared beam **92** emitted from the light marker **82**. In other instances, a camera may define the line-of-sight device **84**.

The position detector **28** illustratively comprises a global positioning system (GPS) receiver configured to detect the absolute position of the antenna **24** relative to reference coordinate system **30**. The reference coordinate system **30** illustratively comprises a geographic coordinate system wherein each coordinate is expressed as an x, y, z (Cartesian) coordinate. In other words, position may be represented by a conventional three axis coordinate system including an x-axis **94** corresponding to latitude, a y-axis **96** corresponding to longitude, and a z-axis **98** corresponding to elevation.

As is known, the GPS receiver **28**, through its antenna (FIG. **6**), receives signals sent by a constellation of GPS satellites (not shown) orbiting the earth. Each satellite continually transmits signals including the time the signal was sent and the orbit for the satellite transmitting the signal. The controller **26** uses the arrival time of each signal to calculate

the distance to each satellite, from which it determines the position of the antenna **24**. More particularly, the controller **26** may determine x, y, and z coordinates (corresponding to latitude, longitude and elevation) of the antenna **24** from the signals received by the position detector **28**. When the position detector **28** determines the absolute position of the antenna **24** along the respective coordinate axes **94**, **96**, and **98**, it sends position signal **32** containing such information to the controller **26**. In the illustrative embodiment of FIG. **5**, the GPS receiver **28** is an independent component communicating with the controller **26**. However, in FIG. **6**, the GPS receiver **28** is integrated within the signal processor **78**. In other illustrative embodiments, the GPS receiver **28** may be incorporated within other components, such as the controller **26**.

The orientation detector **34** is illustratively configured to detect the angular orientation of the antenna **24** about the perpendicular axes **62** and **64** relative to the reference coordinate system **30**. Moreover, the orientation detector **34** transmits orientation signal **36** to the controller **26** proportional to its orientation relative to the reference coordinate system **30**. Illustratively, the orientation detector **34** may comprise a digital compass operably coupled to the support **54**. In an alternative illustrative embodiment, the orientation detector **34** may comprise angular or rotation sensors configured to sense the rotational movement of the antenna **24** relative to the support **54**. In one embodiment, these rotation sensors may comprise feedback elements integral with orientation actuators **76**, such as servomotors, configured to rotate the antenna **24**.

The spatial processor **44** of controller **26** manipulates data from the position signal **32** transmitted by the position detector **28** and from the orientation signal **36** transmitted by the orientation detector **34** to calculate the position of the signal transmission source **12**. More particularly, the controller **26** determines directional vectors **40***a* and **40***b* (FIGS. **1-4**) at data acquisition locations **15***a* and **15***b* based upon the data from position signal **32** and orientation signal **36**.

With reference to FIG. **9**, the coordinates of a first location A of antenna **24** (corresponding to data acquisition location **15***a*) are sensed by position detector **28***a* and stored in memory **52** of controller **26**. Likewise, the coordinates of a second location B of antenna **24** (corresponding to data acquisition location **15***b*) are sensed by position detector **28***b* and stored in memory **52** of controller **26**. Finally, the orientation of the antenna **24***a* and **24***b* at first and second locations A and B are also known by orientation detector **34***a* and **34***b*. It should be appreciated that the position signals **32** and orientation signals **36** from first and second locations A and B may be contemporaneously acquired by sensors **22***a* and **22***b* of spatially distinct systems **10***a* and **10***b*, or acquired successively at distinct times by a single system **10** moved from position A to position B. Further, any number of readings may be acquired at any number of data acquisition locations **15**.

The spatial processor **44** uses trigonometry, and more particularly, triangulation to determine the location of the signal transmission source **12** from data acquired by the locating system **10** at first and second data acquisition locations **15***a* and **15***b*. Triangulation is the known process of determining the location of an unknown point by measuring angles to it from known points at either end of a fixed baseline, rather than measuring distances from the known points to the unknown point directly. The distance to, and hence the coordinates of, an unknown point may be found by calculating the length of one side of a triangle, given measurements of angles and sides of the triangle formed by that point and two other known reference points. The following equations apply in flat or Euclidean geometry, such that inaccuracies may develop if distances become appreciable compared to the curvature of the Earth. As such, these equations may be replaced with others derived using spherical trigonometry.

While different known trigonometric relationships may be utilized by the spatial processor **44**, the following equations show one illustrative embodiment in connection with representative FIG. **8**. The distance "b" from point A to point C, and the distance "c" from point B to point C, may be calculated by using the distance "a" from point A to point B. More particularly, the spatial processor **44** may use the law of sines for calculating the lengths of the sides of a triangle:

$$\frac{\sin\alpha}{c} = \frac{\sin\beta}{b} = \frac{\sin\gamma}{a}$$

Since the distance "a" is known (from the position signals taken at acquisition points **15***a* and **15***b*), the lengths of the other two sides "b" and "c" may be calculated as:

$$b = \frac{a \cdot \sin\beta}{\sin\gamma} \text{ and } c = \frac{a \cdot \sin\alpha}{\sin\gamma}$$

Given the known values for angles α and β, and the known values for lengths a, b and c, the full coordinates of the unknown point C (corresponding to the electromagnetic radiation source **12**) may then be calculated.

The locating system **10** further illustratively includes a transmitter **102** operably coupled to communication control **48** of the controller **26**. The transmitter **102** may comprise a conventional radio frequency transmitter or form part of a transceiver for providing communication with external receivers and/or transceivers (not shown). In certain illustrative embodiments as further detailed herein, the transmitter **102** provides communication with a base unit **112** (FIG. **5**) or a second locating system **10**. As illustrated in FIG. **6**, the transmitter **102** may comprise a satellite phone to provide two-way communication with another sensor assembly **22**. The transmitter **102** may also provide communication with an aerial vehicle **104**.

The aerial vehicle **104** may be a conventional airplane or unmanned aerial vehicle (UAV) configured to carry a payload. As shown in FIG. **6**, the UAV **104** may be supported within a launch tube **105** coupled to the vehicle **72**. Conventional propulsion means, such as pneumatics or combustion devices, may be used to launch the UAV **104** from the tube **105**. The UAV **104** is directed by the controller **26** to travel to predefined coordinates. The aerial vehicle **104** is illustratively configured to carry a marker or beacon **106**. Upon instruction from the controller **26**, the marker **106** is dropped by the aerial vehicle **104** proximate the detected radiant energy transmission source **12**. A joystick **107** may be operably coupled to the transmitter **102** to manually control flight of the UAV **104**.

The marker **106** may comprise a visible beacon, such as a smoke generator or a strobe light. Alternatively, the marker **106** may comprise an electronic beacon, such as an IR beacon, that may be tracked by appropriate equipment, such as IR sensing cameras or goggles. It certain other embodiments, the aerial vehicle **104** may drop other payload instead of, or in addition to, the marker **106**. Such payload may comprise survival supplies, such as food and water, or explosives.

With further reference to FIG. **5**, the locating system **10** may also include camera **108** in addition to the line-of-sight device **84**, such as a video or still camera. The camera **108** is

in communication with image processor **50** of the controller **26**, which may display the images on a display **110**, download and store images within memory **52**, and/or transmit the images to a base unit **112** via transmitter **102**. In one illustrative embodiment, the camera **108** may be an infrared or thermal imaging camera. More particularly, the camera **108** and/or line-of-sight device **84** may determine and verify targets designated by respective range finders **38** or light markers **82** of other sensor assemblies **22**.

In the illustrative embodiments shown in FIGS. **1-4**, first and second vehicles **72***a* and **72***b* may be provided with nearly identical locating systems **10***a* and **10***b*, each in communication with a separate controller **26***a* and **26***b*. In certain embodiments, the locating systems **10***a* and **10***b* may both be in communication through transceivers with a single controller **26** located at base unit **112**.

FIG. **10** illustrates a handheld embodiment of the electromagnetic radiation sensor assembly **22'**. The sensor **22'** includes may similar elements to the sensor **22** illustrated in FIGS. **6-8**, with like components identified with like reference numbers. However, instead of having a mast **70** mounted to a vehicle **72**, the sensor **22'** is configured to be carried by a user. More particularly, the antenna **24** is supported by a handle **114** including a grip portion **116** to receive the fingers of a user. An accessory housing **117** is supported by the antenna **24** and illustratively receives the range finder **38**, the light marker **82**, and line-of-sight device **84**. Communication with the controller **26** may be through a cable **118** or wirelessly through transceiver **102**. In yet other illustrative embodiments, the controller **26** may be supported within the housing **117**. A two-stage trigger **120** may be supported by the handle **114** and is illustratively configured to activate the range finder **38** in a first position and activate the light marker **82** in a second position.

With reference to FIG. **11**, an illustrative method of detecting a transmission source of electromagnetic radiation begins at block **152**. Next, variables are set by the controller **26**, including variable "x" which is set equal to 1 at block **154**. A directional antenna **24** is positioned initially at a first location **15***a* at block **156**. More particularly, the user positions the antenna **24** at first location **15***a* illustratively by driving the vehicle **72** to the desired location **15***a*, or by walking to the desired location **15***a*. At block **158**, the antenna **24** detects the electromagnetic radiation signal **16** at the first location **15***a*. The controller **26** at block **160** then aligns the directional antenna **24** at the first location **15***a* with the strongest detected direction of the electromagnetic radiation signal **16**.

Next, at block **162**, the range finder **38** directs a light from the first location **15***a* in the direction of the aligned directional antenna **24**. A distance to an aligned object along the light beam is then returned to the range finder **38**. If no obstruction **18** exists at block **164**, then the RF source **14** should be visible through the line-of-sight device **84**. If so, an appropriate response may be taken at block **166**. If an obstruction **18** exists, such as woods or ground clutter **19**, then the RF source **14** may not be visible through the line-of-sight device **84**. If the RF signal source **12** cannot be viewed at block **164**, then the process continues to block **168**. If the number of data acquisition points **15** is not greater than 1 (i.e. x=1), then at block **170** the value of x is increased by 1 and the process returns to block **156**. At block **156** the antenna **24** is repositioned to a second data acquisition point **15***b*. The process then continues through process blocks **158**, **160**, and **162** as detailed above. More particularly, the directional antenna **24** detects the electromagnetic signal **16** at second location **15***b*. The directional antenna **24** is then aligned at the second location **15***b* with the strongest detected direction of electromagnetic radiation signal **16**. Light source from the range finder **38** is then directed in alignment with the antenna **24** in the direction toward the RF source **12**. At block **164**, again the query is posed regarding the visibility of the RF signal source **12**. If visible from location **15***b*, then a response to the RF signal source **12** is made. If not, then the process continues to decision block **168**. Since the signal source **12** has been detected from two different data acquisition points **15***a* and **15***b* (i.e. x>1), the process continues to process block **172**.

Next, at block **172** the controller **26** calculates the expected intersection point of the light sources from the first and second locations **15***a* and **15***b*, which should correspond to the RF source **12**. More particularly, the spatial processor **44** illustratively uses triangulation to calculate the coordinates of RF source **12** based upon the known locations of data acquisition points **15***a* and **15***b* in the manner detailed above in connection with FIG. **8**.

If the light beam reflected back to the range finder **38** at point **15***b* does not intersect the light beam reflected back to the range finder **38** at point **15***a*, then the controller **26** identifies an obstruction **18** intermediate the detector **22** and the RF source **12**. At block **176**, the controller **24** may dispatch an aerial vehicle **104** to drop a marker **106** at the RF source **12**. The marker **106** then may be utilized by ground crews to locate the RF source **12**.

While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

The invention claimed is:

1. An electromagnetic radiation source locating system comprising:

a first vehicle;

a first electromagnetic radiation receiving device configured to detect a radiant energy transmission;

a first directional antenna operably coupled to the first electromagnetic radiation receiving device;

a first support operably coupled to the first electromagnetic radiation receiving device for orienting the first directional antenna in a direction toward the radiant energy transmission;

a first position detector in communication with a controller and configured to detect a position of the first directional antenna relative to a reference coordinate system;

a first orientation detector in communication with the controller and configured to detect an orientation of the first directional antenna and provide a first directional signal indicative thereof to the controller;

a second vehicle;

a second electromagnetic radiation receiving device configured to detect the radiant energy transmission;

a second directional antenna operably coupled to the second electromagnetic radiation receiving device;

a second support operably coupled to the second electromagnetic radiation receiving device for orienting the second directional antenna in a direction toward the radiant energy transmission;

a second position detector configured to detect the position of the second directional antenna relative to the reference coordinate system;

a second orientation detector in communication with the controller and configured to detect the orientation of the

second directional antenna and provide a second directional signal indicative thereof to the controller;

wherein the controller is configured to determine a second directional vector to the radiant energy transmission source, the controller including a spatial processor configured to calculate the location of the radiant energy transmission source based upon at least two different directional vectors;

a first range sensor adapted to direct a first light source along a first one of said at least two directional vectors and providing a first distance signal which is communicated to the controller; and

a second range sensor for directing a second light source along a second one of said at least two directional vectors and providing a second distance signal to the controller.

2. The electromagnetic radiation source locating system of claim **1**, wherein each of the first position detector and the second position detector comprises a global positioning system receiver.

3. The electromagnetic radiation source locating system of claim **1**, wherein each of the first orientation detector and the second orientation detector comprises a digital compass.

4. The electromagnetic radiation source locating system of claim **1**, further comprising a first actuator configured to move the first directional antenna about at least two perpendicular axes; and a second actuator configured to move the second directional antenna about at least two perpendicular axes.

5. An electromagnetic radiation source locating system comprising:

a first vehicle;

a first electromagnetic radiation receiving device configured to detect a radiant energy transmission;

a first directional antenna operably coupled to the first electromagnetic radiation receiving device;

a first support operably coupled to the first electromagnetic radiation receiving device for orienting the first directional antenna in a direction toward the radiant energy transmission;

a first position detector in communication with a controller and configured to detect a position of the first directional antenna relative to a reference coordinate system;

a first orientation detector in communication with the controller and configured to detect an orientation of the first directional antenna and provide a first directional signal indicative thereof to the controller;

a second vehicle;

a second electromagnetic radiation receiving device configured to detect the radiant energy transmission;

a second directional antenna operably coupled to the second electromagnetic radiation receiving device;

a second support operably coupled to the second electromagnetic radiation receiving device for orienting the second directional antenna in a direction toward the radiant energy transmission;

a second position detector configured to detect the position of the second directional antenna relative to the reference coordinate system;

a second orientation detector in communication with the controller and configured to detect the orientation of the second directional antenna and provide a directional signal indicative thereof to the controller;

wherein the controller is configured to determine a directional vector to the radiant energy transmission source, the controller including a spatial processor configured to calculate the location of the radiant energy transmission source based upon at least two different directional vectors;

a transmitter operably coupled to the controller;

an aerial vehicle in communication with the transmitter; and

a marker carried by the aerial vehicle and configured to be dropped proximate the radiant energy transmission source.

6. A method of detecting a transmission source of electromagnetic radiation, the method comprising the steps of:

positioning a first directional antenna at a first location;

detecting an electromagnetic signal at the first location with the first directional antenna;

aligning the first directional antenna at the first location based upon the strength of the detected electromagnetic radiation signal;

directing a first light source from the first location in a direction of the aligned first directional antenna;

positioning a second directional antenna at a second location;

detecting the electromagnetic signal at the second location with the second directional antenna;

aligning the second directional antenna at the second location based upon the strength of the detected electromagnetic radiation signal;

directing a second light source from the second location in a direction of the aligned second directional antenna; and

calculating an expected intersection point of the first light source from the first location and the second light source from the second location.

7. The method of claim **6**, further comprising the step of dropping a marker from an aerial vehicle.

8. The method of claim **6**, further comprising the step of detecting an obstruction between the first or second light source and the expected intersection point.

9. The method of claim **6**, wherein the obstruction detecting step comprises comparing a detected distance to a calculated distance from the first or second light source to the intersection point.

10. The method of claim **6**, wherein the electromagnetic signal comprises a radio frequency signal.

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