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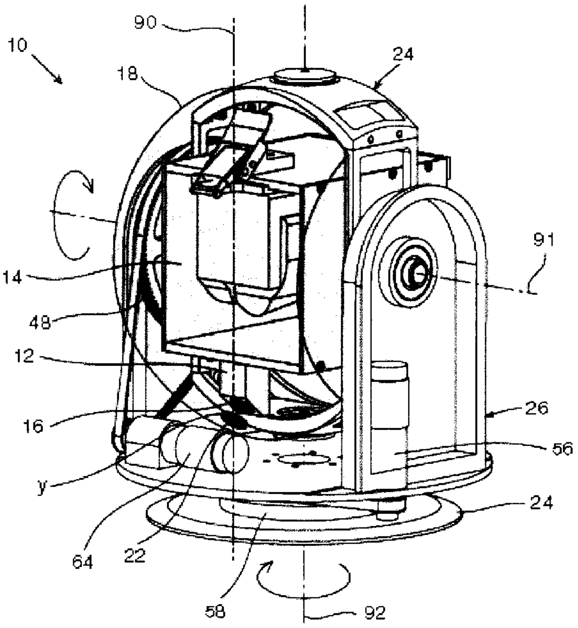

FIG.1

(57) Abstract: An aerial camera gimbal apparatus may include a magnet mounting arranged at a vertical mid-plane of a camera mounting frame. A first magnet may be fixedly mated onto the magnet mounting. An attachment structure may be fixedly mated to the rear portion of the inner joint. A second magnet may be mated to the attachment structure. The first magnet and the second magnet are positioned in a proximal non-contact relationship with each other to provide a magnetizing effect on each other. The camera mounting frame when mounted with a camera is arranged so that the centre of gravity of the assembly is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system. The apparatus reduces errors caused by vibrations from an aircraft on the line of sight of the aerial camera.

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AERIAL CAMERA GIMBAL APPARATUS AND ASSOCIATED METHOD THEREOF

TECHNICAL FIELD

The present disclosure relates to aerial cameras and more particularly to an aerial camera gimbal apparatus for reducing imaging errors caused by aircraft vibrations on the line of sight of an aerial camera.

BACKGROUND

Surveying of forest resources, flooding of land, and other surveys done by air are typically performed in association with a forester or a wildlife / wilderness / aerial observation expert. Such surveying requires a camera and other useful instruments present on the surveying aircraft / airplane in order to record pictures for analysis. Aircraft-based surveys may lead to the loss of valuable personnel and assets if the aircraft is exposed to harmful situations. Such requirements and possible adverse situation effects significantly impact air survey project time and budget.

Currently, an aerial camera gimbal can be set up on the aircraft structure and the motion of the camera can be controlled remotely from a ground station as well as from the airplane. This arrangement allows the camera gimbal to send tremulous pictures to the ground by using a long-range data communication system. Such an arrangement is very convenient for a variety of survey applications. The camera gimbal includes two important parts. The first part is a gimbal mechanism with camera and sensor installed at the centre of the gimbal mechanism. The other part is an image processing / programming part which stabilizes the images. Since a moving platform such as an aircraft induces acceleration, frictional forces and forces due to mass imbalance, effects known as disturbances to the input must be suppressed.

Motion control of the camera gimbal can be divided into two parts. The first part is controlled by a feedback control system in order to move the gimbal according to a reference command, and at the same time stabilize the gimbal where the camera is attached.

Jitter reduction is also required to be considered in the motion controller. The second part is the stabilizing of images conducted by an image processing / programming technique.

There are presently no techniques for reducing or eliminating the vibrations from the aircraft structure to the camera gimbal as aforementioned. Current literature describes only the design structure of the aerial camera gimbal for mounting onto the body of an aircraft.

In view of the foregoing problems, a need remains for an apparatus, system, and/or technique that can overcome at least one of the above-noted shortcomings.

SUMMARY

In view of the foregoing background, it is therefore an object of the non-limiting exemplary embodiments to provide an aerial camera gimbal system, apparatus, device, and/or technique. The non-limiting embodiments of this disclosure satisfy the need indicated in the background by providing an aerial camera gimbal apparatus utilizing a camera mounting frame incorporating a magnetizing mechanism to reduce errors caused by vibrations from an aircraft on the line of sight of an aerial camera. This and other objects, features, and advantages of the invention are provided by the aerial camera gimbal system for reducing the errors caused by the vibrations from the aircraft on the line of sight of the camera.

In accordance with a first aspect of this disclosure, there is disclosed an apparatus (e.g., portions of an aerial camera gimbal system) for reducing effects of vibrations on a line of sight of an aerial camera. The apparatus comprises a magnet mounting arranged at a vertical mid-plane of a camera mounting frame, the magnet mounting having a first magnet fixedly mated thereon; an attachment structure fixedly mated to the camera mounting frame; and a second magnet fixedly mated to the attachment structure. The first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other. A centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

In accordance with one embodiment of this disclosure, the gimbal system comprises a control system for maintaining the line of sight of the camera to within an angular measurement error of less than two degrees.

In accordance with one embodiment of this disclosure, the gimbal system further comprises a base on which the outer joint is rotatably mounted, and wherein the base is adapted to be attached to a predetermined portion of an aircraft structure.

In accordance with one embodiment of this disclosure, the outer joint comprises: a base plate rotatably mated to the base; a pair of outer frames extending from opposed sides of the base plate; mounting mechanism located on each of the pair of outer frames from which the inner joint is rotatably mated; a first tooth ring centrally mounted at a lower face of the base plate; and a second tooth ring mated to one of the outer frames, wherein a centre of the second tooth ring and centre points of the mounting mechanism define the tilt axis of the gimbal system.

In accordance with one embodiment of this disclosure, the inner joint comprises: a pair of upper and lower arcuate sections; and a pair of planar sections having a centrally located aperture for attachment of the mounting mechanism, wherein a centre of the first tooth ring and centre points of the upper and lower arcuate sections of the inner joint define the azimuth axis of the gimbal system.

In accordance with one embodiment of this disclosure, the camera mounting frame comprises: a camera holder having an upper portion in sliding engagement with a top end portion of the camera mounting frame; and a locking latch for detachably locking the camera to the camera mounting frame.

In accordance with one embodiment of this disclosure, the control system comprises: a tilt controller for controlling a tilt motor for maintaining an elevation line of sight of the camera; an azimuth controller for controlling an azimuth motor for maintaining an azimuth line of sight of the camera; a tilt sensor mounted at an end portion of the tilt motor for detecting a tilt angle of the gimbal system; and an azimuth sensor mounted at an end portion of the azimuth motor for detecting an azimuth angle of the gimbal system.

In accordance with one embodiment of this disclosure, the azimuth motor is mounted on the base; and wherein the azimuth motor is communicatively mated to the first tooth ring by a first belt for controlled movement of the outer joint.

In accordance with one embodiment of this disclosure, the tilt motor is mounted on the base plate of the outer joint; and wherein the tilt motor is communicatively mated to the second tooth ring by a second belt for controlled movement of the inner joint.

In accordance with a second aspect of this disclosure, there is disclosed a system for reducing effects of vibrations on a line of sight of an aerial camera. The system comprises a magnet mounting arranged at a vertical mid-plane of a camera mounting frame, the magnet mounting having a first magnet fixedly mated thereon; an attachment structure fixedly mated to the camera mounting frame; and a second magnet fixedly mated to the attachment structure. The first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other. A centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

In accordance with a third aspect of this disclosure, there is disclosed a method of reducing effects of vibrations on a line of sight of an aerial camera. Such a method may include the steps of: arranging a magnet mounting at a vertical mid-plane of a camera mounting frame; fixedly mating a first magnet to the magnet mounting; providing an attachment structure to the camera mounting frame; and fixedly mating a second magnet to the attachment structure. The first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other. A centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

The method may further comprise the steps of: providing the gimbal system with a control system for maintaining the line of sight of the camera to within an angular measurement error of less than two degrees; mounting the camera to the camera mounting frame with a camera holder having an upper portion in sliding engagement with a top end portion of the camera mounting frame; and providing a locking latch for detachably locking the camera to the camera mounting frame.

Advantages of the invention

The combination of the claimed features of this invention provides a novel way of enabling the line of sight of an aerial camera to be maintained to within an angular measurement error of less than two degrees when utilized on an aircraft as described.

There has thus been outlined, rather broadly, the more important features of this disclosure in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are additional features of this disclosure that will be described hereinafter and which will form the subject matter of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the disclosure are described hereinafter with reference to the following drawings, in which:

FIG. 1 is a perspective view showing a rear side of the aerial camera gimbal system, in accordance with the non-limiting exemplary embodiments;

FIG. 1a is a representational view of the apparatus when mounted on an aircraft;

FIG, 2 is a perspective view showing a front side of the apparatus, in accordance with the non-limiting exemplary embodiments;

FIG. 3 is a side elevational view of the apparatus as shown in FIG. 1;

FIG. 4 is a perspective view of the outer joint;

FIG. 5 is a perspective view showing the inner and outer joints;

FIG. 6 is an exploded view showing the inner joint, mounting assembly and the camera mounting frame;

FIG. 7 is a perspective view showing the assembling of camera to the camera mounting frame; and

FIG. 8 is a schematic block diagram showing the configuration of the aerial camera gimbal system.

Those skilled in the art will appreciate that the figures are not intended to be drawn to any particular scale; nor are the figures intended to illustrate every embodiment of the invention. This disclosure is not limited to the exemplary embodiments depicted in the figures or the shapes, relative sizes or proportions shown in the figures.

DETAILED DESCRIPTION

Non-limiting exemplary embodiments, which are provided as representative embodiments for purpose of illustration, will now be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as limited to or by the specific embodiments set forth herein. These embodiments are provided so that this specification will be thorough and complete, and will fully convey the true scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the figures.

Embodiments of this disclosure relate to an aerial camera gimbal sytsem, apparatus, structure, and/or device. In particular, the apparatus provides a means for reducing errors caused by vibrations transmitted from an aircraft carrying the aerial gimbal apparatus and an aerial camera associated therewith on the line of sight of the aerial camera.

Referring to the figures in general, the aerial camera gimbal apparatus 10 may include a magnet mounting 12 arranged at a vertical mid-plane 90 of a camera mounting frame 14. A first magnet 16 may be fixedly mated onto the magnet mounting 12. An attachment structure 18 may further be fixedly mated to the top rear portion of the inner joint 24. A second magnet 22 may be fixedly mated to the attachment structure 18. The arrangement is such that the first magnet 16 and the second magnet 22 are in a proximal non-contact relationship with each other to provide a magnetizing effect on each other. The camera mounting frame 14 when mounted with a camera 40 may further be arranged such that the centre of gravity of the assembly is situated at an intersection x of a tilt axis 91 provided by an inner joint 24 and an azimuth axis 92 provided by an outer joint 26 of a two-axis gimbal system 60.

As shown in FIG. 1, the camera 40 is mounted on the camera mounting frame 14 which is in turn mounted along the tilt axis 91 of the inner joint 24. The camera mounting frame 14 can move freely in two degrees of freedom within a limited small angle. In this way, the camera mounting frame 14 and the camera 40 are kept at a centre position by the magnetic field created by the first magnet 16 and the second magnet 22, such that vibrations may be damped out effectively. As shown in FIGS. 1-4, the apparatus 10 may include a base 28 on which the outer joint 26 is rotatably mounted. The base 28 may be suitably constructed to be attached to a predetermined portion of an aircraft structure 30. FIG. 1a shows a mounting orientation of the apparatus 10, showing the tilt angle z at 0° to 70°. Such an angular tilt range is best for the camera 40 to be held within the measurement error of less than 1 degree. However, it is envisaged that the tilt angle z can vary between -10° to 110° and the azimuth angle can rotate 360° in other configurations. From these ranges, the first magnet 16 and the second magnet 22 can efficiently diminish the errors caused by the vibrations.

Referring to FIGS. 4 and 5, to arrange the centre of gravity of the assembled camera 40 and mounting frame 14 as close as possible to the intersection x of the tilt axis 91 and the azimuth axis 92, it is envisaged that conventional mechanical and dynamic balancing techniques can be employed respectively by those skilled in the art. For example, the mechanical balancing can be achieved by designing a symmetrical structure for the camera mounting frame 14 and inner joint 24. Dynamic balancing can next be tested by using for example an external motor (not shown) for rotating the inner joint 24 and then using a dynamic balancing machine (not shown) to measure any deviated centrifugal force and adjustments made accordingly.

Referring to FIGS. 4-6, the outer joint 26 may include a base plate 32 rotatably mounted to the base 28. A pair of arch-shaped outer frames 34 may extend from opposed sides of the base plate 32. A mounting mechanism 36 may further be located on each of the pair of outer frames 34 from which the inner joint 24 may be rotatably mounted. A first tooth ring 38 may be centrally mounted at a lower face of the base plate 32 as shown in FIG. 4.

Referring to FIG. 5, the inner joint 24 may include a pair of upper and lower arcuate sections 42 and a pair of planar sections 44. Each of the pair of planar sections 44 may include a centrally located aperture 46 for attachment of the mounting mechanism 36. The azimuth axis 92 may further pass through the centre of the first tooth ring 38 and the centre points of the pair of upper and lower arcuate sections 42 of the inner joint 24. A second tooth ring 48 may be mounted to the inner joint 24. This second tooth ring 48 may be located next to an inner side of the outer frames 34 of one of the outer joint 26 to facilitate controlled movement of the inner joint 24. The centre of the second tooth ring 48 and centre points of the mounting mechanism 36 provide the tilt axis 91 of the gimbal system 60. As best shown in FIGS. 5 and 6, the mounting mechanism 36 may include a pair of bearing 49 and bush 54 assembled to provide a low friction rotational movement of the inner joint 24.

Referring to FIGS. 2, 3 and 8, the apparatus 10 may include a control system 50 for maintaining the line of sight 93 of the camera 40 to within an angular measurement error of less than two degrees. Such a control system 50 may include a tilt controller 52 for controlling a tilt motor 64 for maintaining the elevation line of sight of the camera 40. The control system 50 may further include an azimuth controller 53 for controlling an azimuth motor 56 for maintaining the azimuth line of sight of the camera 40. As best shown in FIG. 7, a tilt sensor 53a may be mounted at an end portion of the tilt motor 64 for detecting the tilt angle of the gimbal system 60 and an azimuth sensor 53b may be mounted at an end portion of the azimuth motor 56 for detecting the azimuth angle of the gimbal system 60.

Referring to FIG. 4, the azimuth motor 56 may be mounted on the base plate 32 and may be engaged to the first tooth ring 38 by a first belt 58 for controlled movement of the outer joint 26. It is envisaged that the azimuth motor 56 may include a pinion gear 62 for engaging the first belt 58 which is in turn engaged to the first tooth ring 38. As best shown in FIGS. 3 and 5, the tilt motor 64 may be mounted on the base plate 32 for controlled movement of the inner joint 24. The tilt motor 64 may be communicatively mated to the second tooth ring by a second belt 66. It is envisaged that the tilt motor 64 may also include a pinion gear (not shown) for engaging the second belt 66 which is in turn engaged to the second tooth ring 48.

Referring to FIG. 7, the camera mounting frame 14 may include a camera holder 68 having an upper portion in sliding engagement with a top end portion of the camera mounting frame 14. A locking latch 72 may be located at the top end portion of the camera mounting frame 14 for detachably locking the camera 40 to the camera mounting frame 14.

Referring to FIGS. 1 and 3, the attachment structure 18 for the second magnet 22 is a back cover for the camera 40. As shown in FIG. 3, the proximal non-contact distance y between the first magnet 16 and the second magnet 22 may range between 8 and 10 millimetres, preferably 9 millimetres. The position of the first magnet 16 and the second magnet 22 advantageously maintains the line of sight 93 of the camera 40 to within an angular measurement error of less than one degree. Although, the back cover 18 shown is a convenient structure whereon the second magnet 22 may be affixed, it should be appreciated that any structure capable of holding the second magnet 22 in the position aforementioned may be utilized. It is envisaged that the first magnet 16 and the second magnet 22 may include high strength rear earth magnets capable of holding the camera 40 as described.

The configuration of the apparatus 10 for reducing the line of sight errors is best shown in FIG. 8. The control system 50 may include the tilt controller 52 and the azimuth controller 53 which may be proportional-integral-derivative (PID) controllers. The tilt controller 52 and the azimuth controller 53 may further be of an advanced controller design for an inertial stabilization system for controlling a 2-DOF (2 degrees-of-freedom) gimbal which can be mounted to an aircraft structure 30. An advanced controller is desired in view of the dynamics modelling errors, friction and disturbances from the outside environment which can severely degrade the tracking accuracy of an airborne gimbal. A robust inverse dynamics control and adaptive control may be utilized in an inner loop or gimbal servo-system to control the gimbal motion. Indirect line of sight (LOS) stabilization may be controlled by the outer loop controller. A sensor (not shown) may be utilized to measure a base rate and orientation of the gimbal system 60 with reference to a fixed reference frame.

Referring to FIG. 8, a reference LOS input 93a is shown. This reference LOS input 93a may be a command provided by the user to aim the camera 40 in a certain direction. The control system 50 may next point the camera 40 at the commanded direction, thus providing a line of sight (LOS) output 93. The accuracy of the line of sight 93 is improved by the holding power of the first magnet 16 and the second magnet 22, such that the LOS 93 is held to within an error of one degree of the reference LOS input 93a. As best shown in FIG. 8, the first magnet 16 may be mounted on the camera mounting frame 14 by means of the magnet mounting 12 while the second magnet 22 may be mounted on the attachment structure 18. It is envisaged that one skilled in the art will be able to design the magnet mounting 12 and the attachment structure 18 in such a manner that the first magnet 16 and the second magnet 22 are positioned at between 8 and 10 millimetres of each other.

The invention may include a method of reducing the effects of vibrations on the line of sight 93 of an aerial camera 40. Such a method may include the steps of: arranging a magnet mounting 12 at a vertical mid-plane 90 of a camera mounting frame 14; fixedly mating a first magnet 16 to the magnet mounting 12; providing an attachment structure 18 to the camera mounting frame 14; and fixedly mating a second magnet 22 to the attachment structure 18. The first magnet 16 and the second magnet 22 are in a proximal non-contact magnetizing relationship with each other. The centre of gravity of the camera mounting frame 14 when mounted with a camera 40 thereon is situated at an intersection x of a tilt axis 91 provided by an inner joint 24 and an azimuth axis 92 provided by an outer joint 26 of a two-axis gimbal system 60.

The method may further include the steps of: providing the gimbal system 60 with a control system 50 for maintaining the line of sight 93 of the camera 40 to within an angular measurement error of less than two degrees; adjusting the proximal non-contact distance y between the first magnet 16 and the second magnet 22 to between 8 and 10 millimetres, preferably 9 millimetres, for maintaining the line of sight 93 of the camera 40 to within an angular measurement error of less than one degree; mounting the camera 40 to the camera mounting frame 14 with a camera holder 68 having an upper portion in sliding engagement with the top end portion of the camera mounting frame 14; and providing a locking latch 72 for detachably locking the camera 40 to the camera mounting frame 14.

While the invention has been described with respect to a certain specific embodiment, it will be appreciated that many modifications and changes may be made by those skilled in the art without departing from the scope of the invention. It is intended, therefore, by the appended claims to cover all such modifications and changes as fall within the scope of the invention. In particular, with respect to the above description, it is to be realized that the situationally appropriate or optimum dimensional relationships for the parts of the non-limiting exemplary embodiments may include variations in size, materials, shape, form, function and manner of operation.

CLAIMS

1. An apparatus for reducing effects of vibrations on a line of sight of an aerial camera, the apparatus comprising:

a magnet mounting arranged at a vertical mid-plane of a camera mounting frame, the magnet mounting having a first magnet fixedly mated thereon;

an attachment structure fixedly mated to the camera mounting frame; and

a second magnet fixedly mated to the attachment structure,

wherein the first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other, and

wherein a centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

2. The apparatus according to claim 1, wherein the gimbal system comprises a control system for maintaining the line of sight of the camera to within an angular measurement error of less than two degrees.

3. The apparatus according to claim 1, wherein the gimbal system further comprises a base on which the outer joint is rotatably mounted, and wherein the base is adapted to be attached to a predetermined portion of an aircraft structure.

4. The apparatus according to claim 3, wherein the outer joint comprises:

a base plate rotatably mated to the base;

a pair of outer frames extending from opposed sides of the base plate;

mounting mechanism located on each of the pair of outer frames from which the inner joint is rotatably mated;

a first tooth ring centrally mounted at a lower face of the base plate; and

a second tooth ring mated to one of the outer frames, wherein a centre of the second tooth ring and the centre points of the mounting mechanism define the tilt axis of the gimbal system.

5. The apparatus according to claim 1, wherein the inner joint comprises:

a pair of upper and lower arcuate sections; and

a pair of planar sections having a centrally located aperture for attachment of the mounting mechanism,

wherein a centre of the first tooth ring and centre points of the upper and lower arcuate sections of the inner joint define the azimuth axis of the gimbal system.

6. The apparatus according to claim 1, wherein the camera mounting frame comprises:

a camera holder having an upper portion in sliding engagement with a top end portion of the camera mounting frame; and

a locking latch for detachably locking the camera to the camera mounting frame.

7. The apparatus according to claim 2, wherein the control system comprises:

a tilt controller for controlling a tilt motor for maintaining an elevation line of sight of the camera;

an azimuth controller for controlling an azimuth motor for maintaining an azimuth line of sight of the camera;

a tilt sensor mounted at an end portion of the tilt motor for detecting a tilt angle of the gimbal system; and

an azimuth sensor mounted at an end portion of the azimuth motor for detecting an azimuth angle of the gimbal system.

8. The apparatus according to claim 7, wherein the azimuth motor is mounted on the base; and wherein the azimuth motor is communicatively mated to the first tooth ring by a first belt for controlled movement of the outer joint.

9. The apparatus according to claim 7, wherein the tilt motor is mounted on the base plate of the outer joint; and wherein the tilt motor is communicatively mated to the second tooth ring by a second belt for controlled movement of the inner joint.

10. A system for reducing effects of vibrations on a line of sight of an aerial camera, the system comprising:

a magnet mounting arranged at a vertical mid-plane of a camera mounting frame, the magnet mounting having a first magnet fixedly mated thereon;

an attachment structure fixedly mated to the camera mounting frame; and

a second magnet fixedly mated to the attachment structure,

wherein the first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other; and

wherein a centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

11. The system according to claim 15, wherein the gimbal system comprises a control system for maintaining the line of sight of the camera to within an angular measurement error of less than two degrees.

12. The system according to claim 10, wherein the gimbal system further comprises a base on which the outer joint is rotatably mounted, and wherein the base is adapted to be attached to a predetermined portion of an aircraft structure.

13. The system according to claim 12, wherein the outer joint comprises:

a base plate rotatably mated to the base;

a pair of outer frames extending from opposed sides of the base plate;

mounting mechanism located on each of the pair of outer frames from which the inner joint is rotatably mated;

a first tooth ring centrally mounted at a lower face of the base plate; and

a second tooth ring mated to one of the outer frames,

wherein a centre of the second tooth ring and centre points of the mounting mechanism define the tilt axis of the gimbal system.

14. The system according to claim 10, wherein the inner joint comprises:

a pair of upper and lower arcuate sections; and

a pair of planar sections having a centrally located aperture for attachment of the mounting mechanism, wherein a centre of the first tooth ring and centre points of the upper and lower arcuate sections of the inner joint define the azimuth axis of the gimbal system.

15. The system according to claim 10, wherein the camera mounting frame comprises:

a camera holder having an upper portion in sliding engagement with a top end portion of the camera mounting frame; and

a locking latch for detachably locking the camera to the camera mounting frame.

16. The system according to claim 11, wherein the control system comprises:

a tilt controller for controlling a tilt motor for maintaining an elevation line of sight of the camera;

an azimuth controller for controlling an azimuth motor for maintaining an azimuth line of sight of the camera;

a tilt sensor mounted at an end portion of the tilt motor for detecting a tilt angle of the gimbal system; and

an azimuth sensor mounted at an end portion of the azimuth motor for detecting an azimuth angle of the gimbal system.

17. The system according to claim 16, wherein the azimuth motor is mounted on the base; and wherein the azimuth motor is communicatively mated to the first tooth ring by a first belt for controlled movement of the outer joint.

18. The system according to claim 16, wherein the tilt motor is mounted on the base plate of the outer joint; and wherein the tilt motor is communicatively mated to the second tooth ring by a second belt for controlled movement of the inner joint.

19. A method of reducing effects of vibrations on a line of sight of an aerial camera, the method comprising:

arranging a magnet mounting at a vertical mid-plane of a camera mounting frame;

fixedly mating a first magnet to the magnet mounting;

providing an attachment structure to the camera mounting frame; and

fixedly mating a second magnet to the attachment structure, wherein the first magnet and the second magnet are in a proximal non-contact magnetizing relationship with each other; and

wherein a centre of gravity of the camera mounting frame when mounted with a camera thereon is situated at an intersection of a tilt axis provided by an inner joint and an azimuth axis provided by an outer joint of a two-axis gimbal system.

20. The method according to claim 19, further comprising: providing the gimbal system with a control system for maintaining the line of sight of the camera to within an angular measurement error of less than two degrees.

21. The method according to claim 19, further comprising: mounting the camera to the camera mounting frame with a camera holder having an upper portion in sliding engagement with a top end portion of the camera mounting frame; and providing a locking latch for detachably locking the camera to the camera mounting frame.

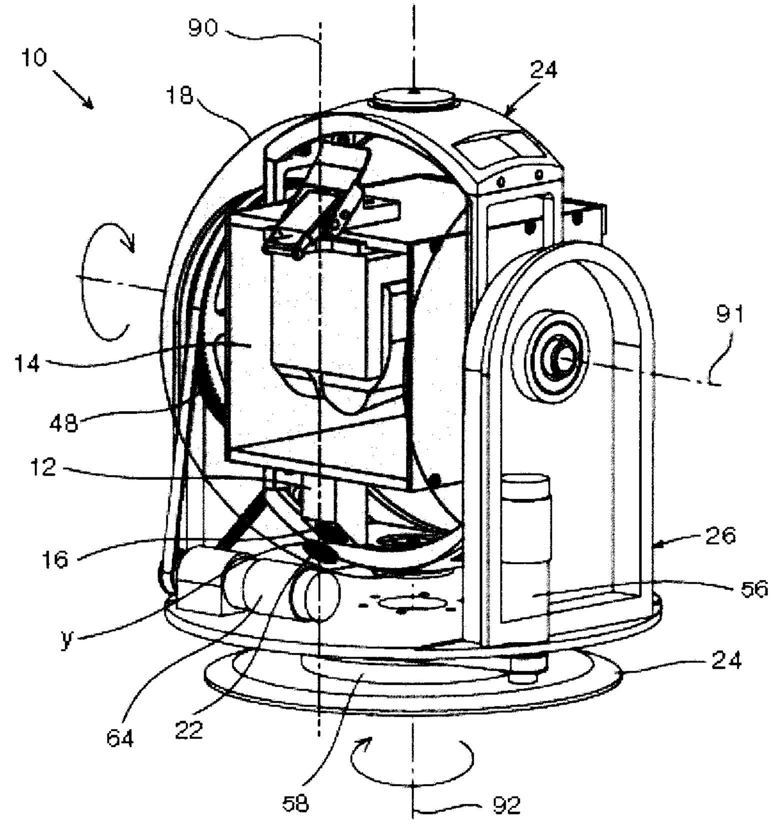

FIG.1

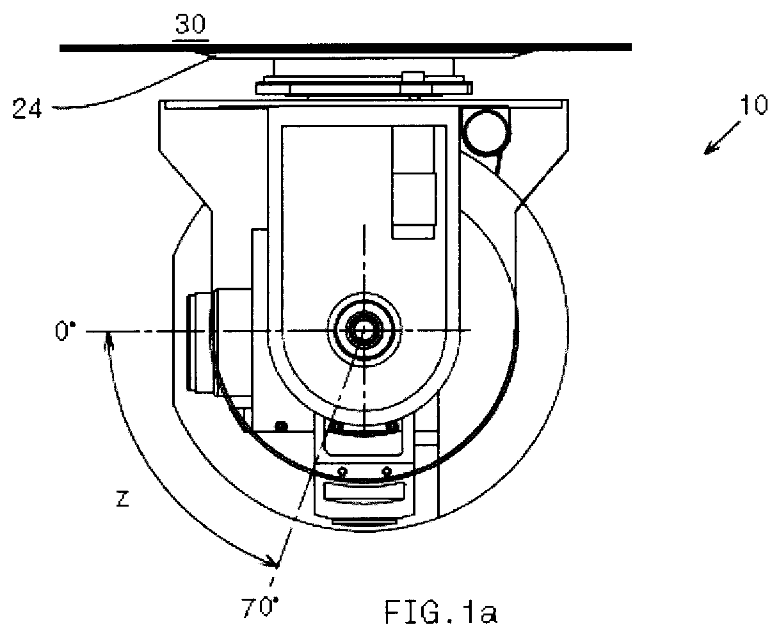

FIG.1a

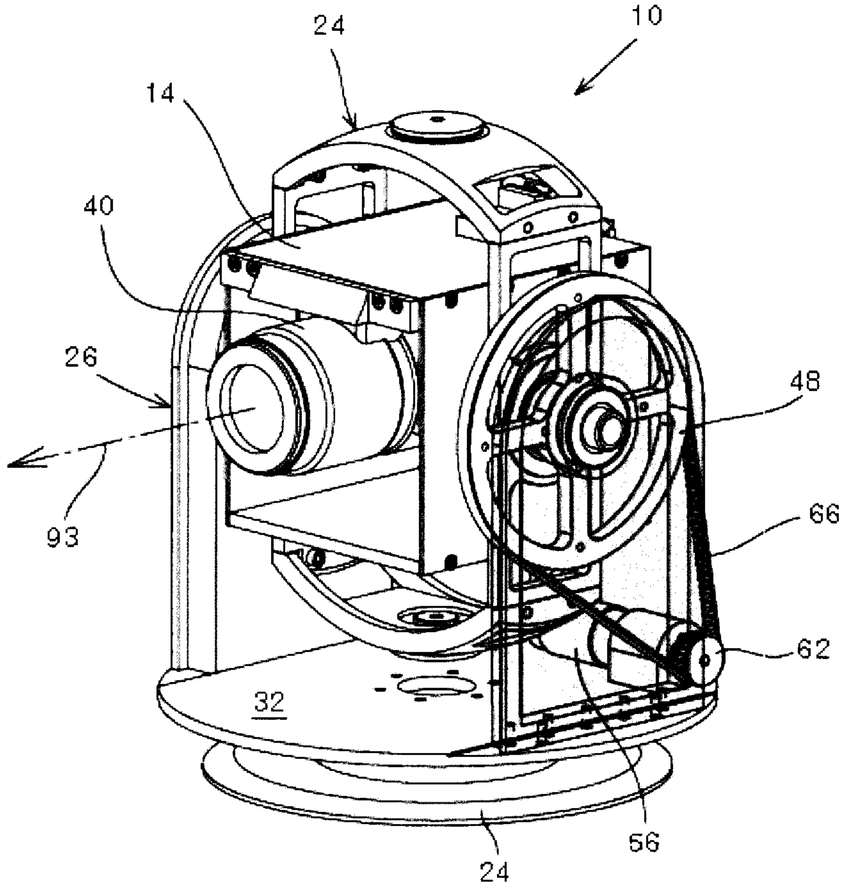

FIG.2

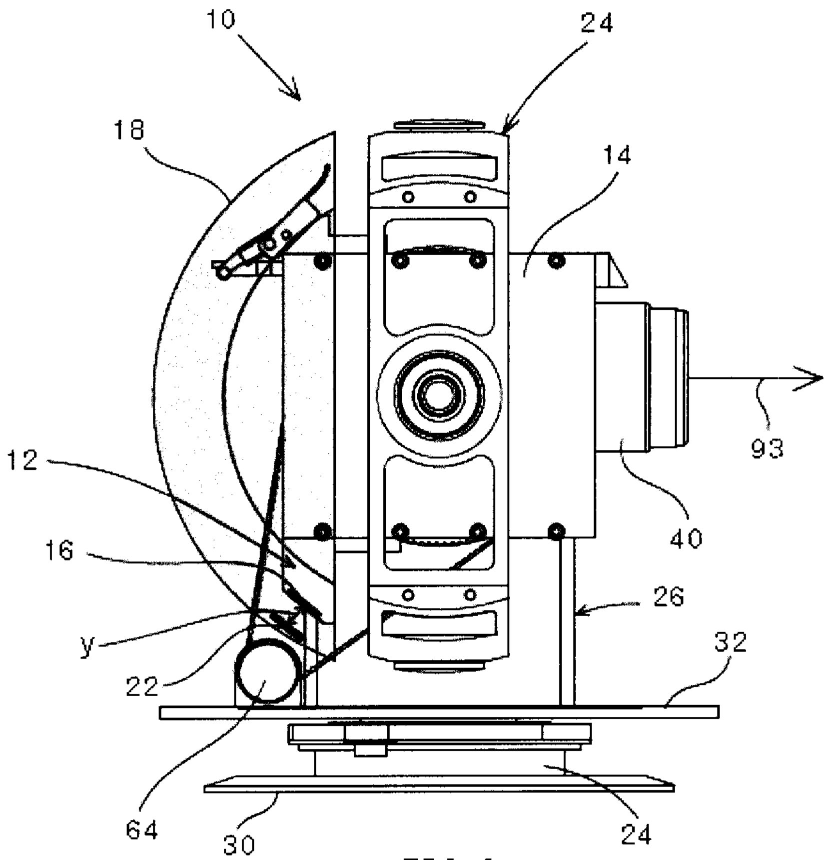

FIG.3

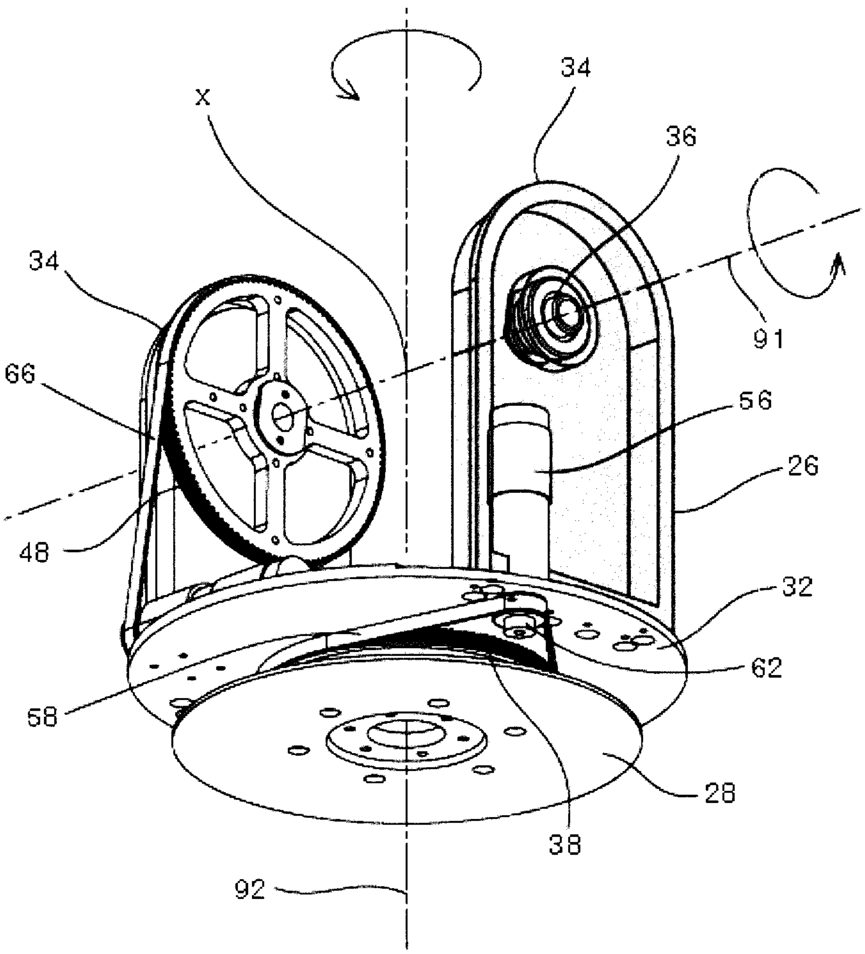

FIG.4

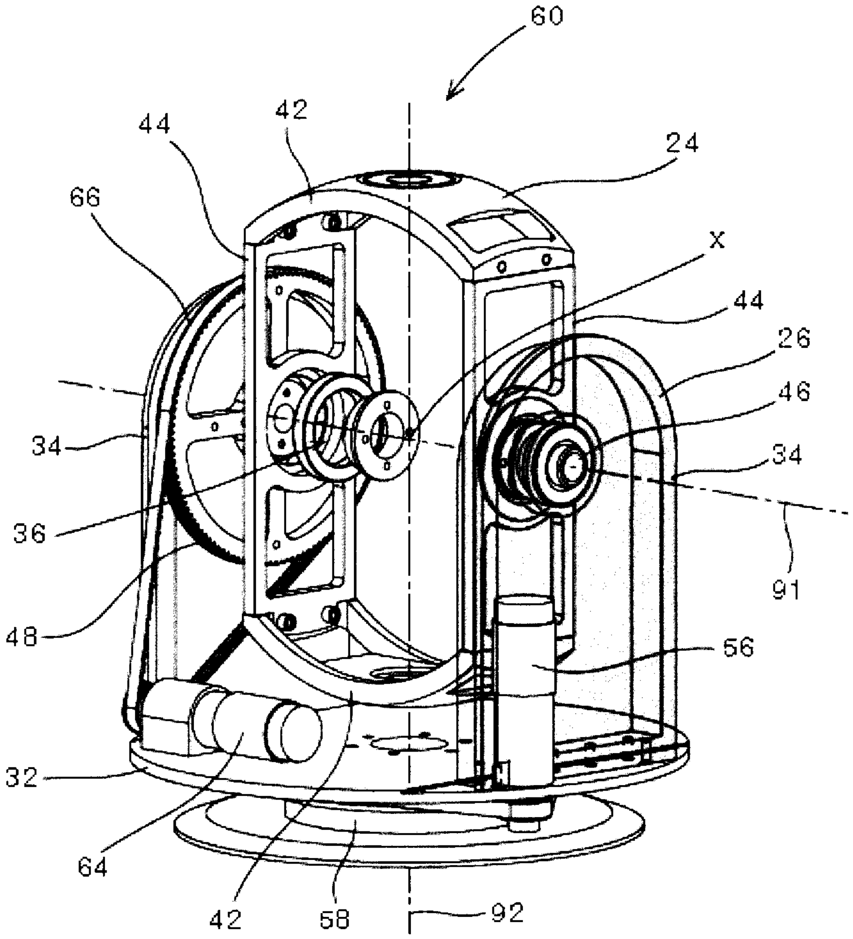

FIG.5

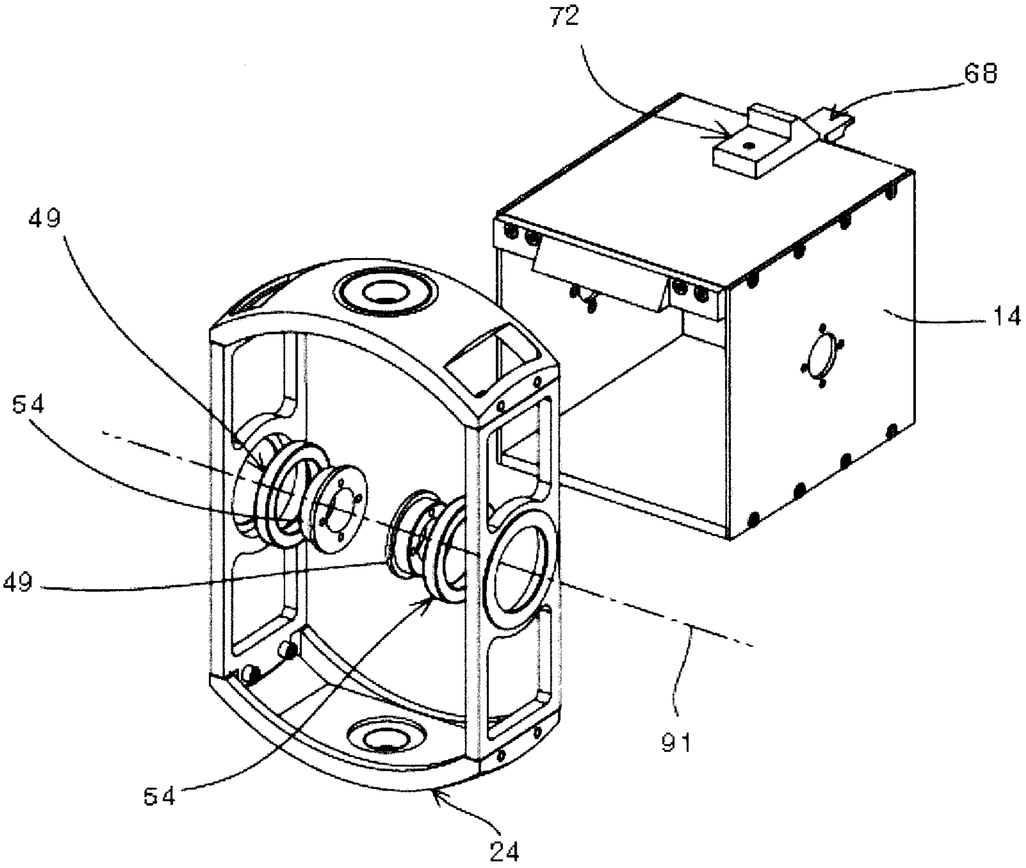

FIG.6

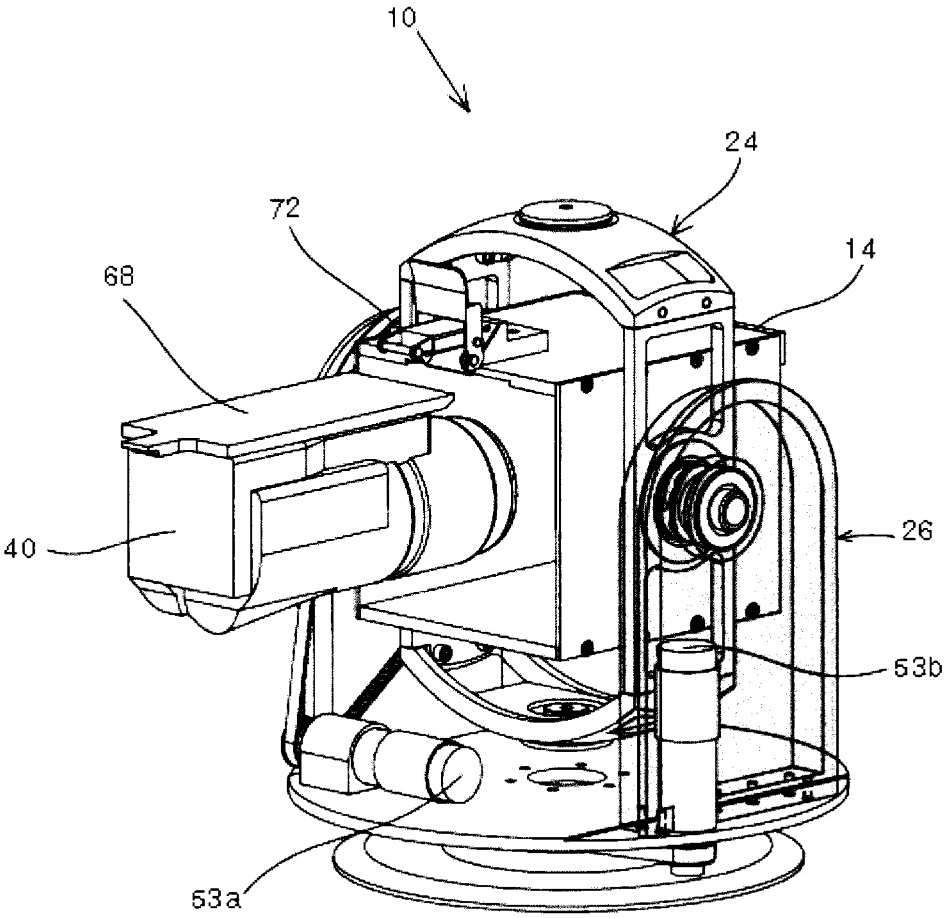

FIG.7

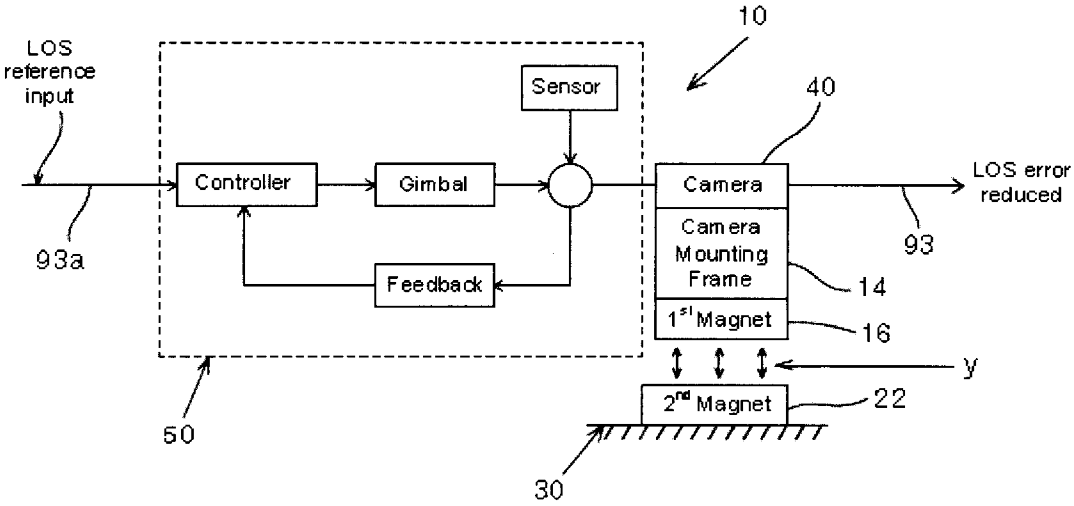
10
LOS reference input
Sensor
40
Controller
Gimbal
Camera
LOS error reduced
Camera Mounting Frame
93a
93
Feedback
14
1st Magnet
16
y
2nd Magnet
22
50
30

FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/TH2015/000011

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G01C 19/02 (2015.01)
CPC - G01C 19/02 (2015.07)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G01C 17/18, 19/02, 19/24; G02B 27/64; G03B 15/00 (2015.01)
CPC - G01C 19/02, 19/24; G02B 27/646; G03B 15/006 (2015.07)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 74/5R, 5.5; 244/3.16, 165; 348/144; 359/554; 396/13, 55 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Patents, Google Scholar, Google.
Search terms used: vibration, oscillation, magnet, gimbal, tilt, gyro, photo, camera, video

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,897,223 A (TRITCHEW et al) 27 April 1999 (27.04.1999) entire document	1-21
Y	US 8,559,802 B1 (MCCLATCHIE et al) 15 October 2013 (15.10.2013) entire document	1-21
Y	US 2012/0263445 A1 (BEASLEY) 18 October 2012 (18.10.2012) entire document	6, 15, 21
Y	US 2010/0019120 A1 (BURNHAM et al) 28 January 2010 (28.01.2010) entire document	8-9, 17-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 August 2015	14 AUG 2015

Name and mailing address of the ISA/	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774