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(54) Title: A STABILIZED PLATFORM FOR A WIRELESS COMMUNICATION LINK

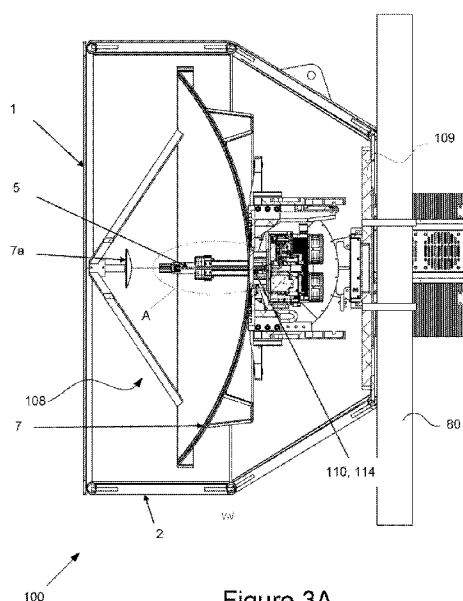


Figure 3A

(57) Abstract: A terrestrial data communications wireless link includes a first link end that has a first directional antenna, a first beacon and a first redirecting assembly coupled to the first directional antenna. The wireless link also includes a second link end having a second directional antenna, a second beacon and a second redirecting assembly coupled to the second directional antenna. In use the first directional antenna and the second directional antenna are maintained in mutual alignment by the first redirecting assembly redirecting the first directional antenna in response to a signal from the second beacon and the second redirecting assembly redirecting the second directional antenna in response to a signal from the first beacon.

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A STABILIZED PLATFORM FOR A WIRELESS COMMUNICATION LINK

TECHNICAL FIELD

- 5 The present invention is directed to an apparatus and method for establishing and maintaining alignment between directional antennas of a terrestrial communications link.

BACKGROUND

10

Any references in the following discussion to methods, apparatus or documents of the prior art are not to be taken as constituting any evidence or admission that they formed, or form part of the common general knowledge.

- 15 Millimeter-wave radio communications apparatus enables the wireless transmission of high speed data between two points. Such apparatus has become an increasingly common method for backhaul of data from cellular networks to a fiber backbone.

- 20 US patent number 6016313 describes multiplexing a plurality of mm-wave antenna arrays to support transport in such a cellular network. In US patents Nos. 6714800, 7062293, 7769347, and 7912506 the use of multiple mm-wave radios to assemble networks for cellular backhaul are disclosed. The systems described in these patents rely on the key advantages of mm-wave
- 25 propagation: large bandwidth, which supports high data rates; and narrow beamwidth, which supports multiple nodes operating from the one site since mutual interference of the radio waves is low. US patent number 7065326 describes a mm-wave system with a particular modulation circuit whose half power beam width is about 0.2 degrees or less.

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Although mm-wave communications systems can support gigabit-per-second data throughput, they have a susceptibility to atmospheric attenuation which limits communications distances to lengths of no more than several miles, and

only in good weather. In US patents numbers 6556836 and 6665546 there are described gigabit-per-second communications at 95 GHz. However these systems require use of a lower frequency backup transceiver in the event of adverse weather. US patents numbers 6169910 and 8090411 and
5 international patent publications WO 2013058673 and WO 2014011087 describe mm-wave systems using special dielectric lens antennas, or multiple feed arrays or switchable focal plane arrays used for electronic beam steering to improve communications and achieve alignment under such conditions.

10 However, as some of these patents describe, the narrow beamwidth at mm-wave frequencies also creates difficulty in correctly aligning two ends of a terrestrial link that are separated by large distances, since the antennas need to point directly at each other to avoid missing each other's narrowly focused beams. US patent number 6587699 describes using an optical alignment
15 method to align antennas at either end of a terrestrial link. US patent number 6611696 claims an alignment method requiring two installers at each end who initially align the antennas visually, and then use the strength of a transmitted tone to manually fine-tune the alignment.

20 US patent number 7680516 claims an automatic alignment technique in which the antenna is mounted on gimbals, but whose positioning data is obtained from GPS signals and must be shared between the two ends. US patent number 6307523 B1 describes an automatic tracking technique specifically for two-way communications with a skyborne target in which a sub-reflector is
25 required in the main path to modulate the main received signal to generate a tracking signal through which the pointing direction may be controlled.

Digital beam forming techniques may also be adapted to indicate the direction of the incoming mm-wave signal and to point the principal axis of the receiver
30 antenna in the correct direction. US patent publication number 20060246863 and international patent publication WO 2011056256 describe such digital beam forming or beam peaking techniques for communications systems,

while US patent number 8558746 describes the construction of a flat panel array antenna for frequencies below 26 GHz.

Referring now to Figures 1 and 2, there are depicted top plan and side views
5 of a terrestrial communications link established by opposed link ends in the form of microwave frequency transceivers and directional parabolic reflector antennas mounted on respective towers.

As previously alluded to, a problem that arises with a system such as that of
10 Figures 1 and 2, which is particularly pronounced where the link operates at millimeter wavelength frequencies, is that it is difficult to maintain mutual alignment of the ends of the link. This problem arises because the operating wavelength is so small that even moderate size antennas (of say 1.2m diameter) have a very narrow beamwidth, which is typically around 0.25
15 degree in the E-band (75 – 85 GHz).

Even if the link is set up correctly initially, with both ends in mutual alignment, a variety of factors may cause the ends to misalign. One reason for misalignment occurring is that the towers at each end may tilt or twist due to
20 wind or other forces. Wind-induced motion at either end of the communications link will cause the center of the transmitted signal beam to completely “miss” the remote antenna, causing lack of any received signal at the remote end and a link outage. Such motion can occur at either, or both, ends of a link.

25

It will be realized that a link outage is highly undesirable and depending on the nature of the traffic being carried it may have very serious ramifications.

In addition to the above problem, it is presently difficult to “fine tune” an initial
30 somewhat coarse alignment of an end of a terrestrial communication link. It would be advantageous if it were possible to subsequently improve upon an initial alignment.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a method for maintaining a first antenna in a desired direction including:

- 5 redirecting the first antenna in response to variations in a beacon signal received at a location proximate or coincident with the first antenna wherein the beacon signal emanates from a remote terrestrial beacon.

10 Preferably the first antenna is mounted to a redirecting assembly arranged for redirection thereof and the step of redirecting the antenna includes controlling actuators of the redirecting assembly.

15 In a preferred embodiment of the invention the redirecting assembly comprises a gimbal having first and second axes. For example, the gimbal assembly may have an elevation axis and an azimuth axis.

20 It is preferred that the first antenna comprises part of a first end of a terrestrial data communication link and said remote beacon is located with a second antenna comprising a second end of the said communication link.

 The beacon may be omnidirectional or alternatively it may be directional so that it has an associated signal beamwidth.

25 Where the beacon is directional the beacon signal beamwidth is typically greater than a beamwidth associated with a data communication signal of the second antenna.

30 Preferably the beacon signal beamwidth is also sufficiently great to accommodate a range of angular perturbations of the first or second antenna from the desired direction. For example, the range of angular perturbations will typically correspond to those expected due to destabilizing motion of a platform upon which the antenna is mounted. The platform may be a telecommunications tower for example.

The method may include, subsequent to acquiring the beacon signal, a step of narrowing said beamwidth for improved accuracy in redirecting the first antenna.

5

The method may also include:

carrying out the step of redirecting the first antenna in response to the beacon signal until the data communication signal is acquired; and

10 then redirecting the first antenna in response to variations in the data communication signal.

The step of redirecting the first antenna in response to variations in the beacon signal may involve applying a monopulse process to thereby improve the accuracy with which the first antenna is redirected.

15

Alternatively, the method may include operating the actuators to mechanically scan for a boresight associated with the beacon signal.

20 In an alternative embodiment of the invention the beacon signal emanates from a beacon located off the desired direction and the beacon signal is received by a second antenna pointed toward the beacon wherein the second beacon antenna is arranged to move in concert with the first antenna.

25 According to a further aspect of the present invention there is provided a software or firmware product comprising tangible machine readable instructions for execution by an electronic processor for implementing the previously described method.

30 According to a further aspect of the present invention there is provided a link end for a terrestrial communications link including:

a directional antenna;

a redirecting assembly mounted to the directional antenna;

one or more actuators coupled to the redirecting assembly;

a control system arranged to control the redirecting assembly in response to variations in the beacon signal.

5 In a preferred embodiment of the invention the redirecting assembly comprises a two axis gimbal. Alternatively, other redirecting assemblies are possible. For example, the redirecting assembly might include a tripod with independently actuated variable length legs for providing tilting of the directional antenna.

10 Preferably the control system includes an azimuth control subassembly in communication with a first actuator of said actuators, wherein the first actuator is arranged to vary an azimuth angle of the gimbal.

15 Preferably the control system includes an elevation control subassembly in communication with a second actuator of said actuators, wherein the second actuator is arranged to vary an elevation angle of the gimbal.

20 In a preferred embodiment of the invention the elevation control subassembly includes an inclinometer.

Preferably the control system is arranged to implement a control system including an inner velocity loop and an outer position loop.

25 It is preferred that the elevation control subassembly and/or the azimuth control subassembly include gyroscopes arranged to sense angular velocity of the antenna.

Preferably the control system is arranged to estimate drift of the gyroscopes and compensate accordingly.

30 In a preferred embodiment of the invention the link end includes a beacon source. For example, the beacon source may comprise a wireless signal generator and a feed or beacon antenna coupled thereto wherein the feed or

beacon antenna is arranged to produce a wider beamwidth than the directional antenna.

5 Preferably the beacon signal beamwidth is also sufficiently great to accommodate a range of angular perturbations of the first or second antennas from the desired direction.

In a preferred embodiment of the invention the beacon generator is comprised of a K-band signal generator.

10

It will be realized that the beacon generator comprise signal generators configured to operate in other frequency bands depending on the requirements of the situation.

15 The control system may include at least one monopulse network.

In a preferred embodiment of the invention the redirection of both first and second antennas is arranged to apply monopulse techniques, allowing redirection of first and second antennas to occur independently and
20 simultaneously.

Alternatively, in a further embodiment of the invention the link end includes a second antenna non-parallel to the directional antenna and arranged to move in concert therewith;

25 wherein the control system controls the redirecting assembly in response to variations in the beacon signal as received by the second antenna.

According to a further aspect of the present invention there is provided a
30 terrestrial link including:

a first link end including a first directional antenna, a first beacon and a first redirecting assembly coupled to the directional antenna; and

a second link end including a second directional antenna, a second beacon and a second redirecting assembly coupled to the second directional antenna;

5 wherein the first directional antenna and the second directional antenna are maintained in mutual alignment by the first redirecting assembly redirecting the first directional antenna in response to a signal from the second beacon and the second redirecting assembly redirecting the second directional antenna in response to a signal from the first beacon.

10 According to a further aspect of the present invention there is provided a terrestrial data communications wireless link comprising:

a first data traffic directional antenna of a first end of the link;

a second data traffic directional antenna of a second end of the link wherein said first antenna and said second antenna point at each other;

15 a first beacon signal directional antenna of the first end of the link pointed at a terrestrial beacon transmitter located off a line between said first and second data traffic antennas;

a second beacon signal directional antenna of the second end of the link pointed at the beacon transmitter;

20 a first redirecting assembly of the first end of the link arranged to redirect said first data traffic antenna and said first beacon antenna;

a second redirecting assembly of the second end of the link arranged to redirect said second data traffic antenna and said second beacon antenna;

25 wherein the first data traffic directional antenna and the second data traffic directional antenna are maintained in mutual alignment by the first redirecting assembly operating in response to a signal from said beacon received by the first said beacon antenna and the second redirecting assembly operating in response to a signal from said beacon received by the second said beacon antenna.

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According to a further aspect of the present invention there is provided a method for increasing the operational range of a high frequency wireless data communications module comprising the steps of:

mounting said communications module to a back face of an interface assembly;

mounting a front face of the interface assembly to an antenna feed of a platform stabilization assembly to thereby couple the communications module
5 to the antenna feed for receiving and transmitting data signals therefrom;

wherein the back face of the interface assembly is arranged to mate with coupling formations of the communications module and

wherein the platform stabilization assembly comprises

a directional antenna;

10 a redirecting assembly mounted to the directional antenna;

one or more actuators coupled to the redirecting assembly;

a control system arranged to control the redirecting assembly in response to variations in the strength of a terrestrial beacon signal.

15 Preferably the interface assembly comprises an interface chassis and an interface plate which comprises the back face of the interface assembly, wherein the interface plate is detachable from the interface assembly for substitution of different interface plates having different communication modules mounted thereto.

20 According to another aspect of the present invention there is provided a method for mounting any one of a plurality of communications modules to a platform stabilization assembly, wherein each of the communications modules is arranged with a different coupling configuration, the method including:

producing a plurality of interface assemblies, each of said assemblies
25 having a back face arranged to mate with a corresponding one of the plurality of communications modules and a common front face arranged to mate with the platform stabilisation assembly;

for a selected one of the communications modules, selecting a corresponding one of the interface assemblies;

mounting the selected communications module to the selected corresponding interface assembly; and

5 mounting the interface assembly to the platform stabilisation assembly.

In a preferred embodiment of the invention one or more of the interface assemblies is comprised of an interface plate and an interface chassis for attachment thereto.

10

According to another aspect of the present invention there is provided an apparatus for coupling any one of a number of different communications modules to an antenna feed of a platform stabilization system, the apparatus comprising:

15 an interface assembly including an interface chassis having a front face arranged to couple to the antenna feed and an interface plate removably fastened to the interface chassis and having a back face arranged to couple to the communications module;

20 wherein the interface plate is one of a number of interface plates each having a back face arranged to complement various coupling configurations of the different communications modules

According to a further aspect of the present invention there is provided an interface assembly including:

25 a back face for coupling to a communications module; and

a front face arranged for coupling to an antenna feed of a platform stabilization assembly to thereby couple said electronic circuitry thereto and

to couple the communications module to the antenna feed for receiving and transmitting data signals therefrom;

wherein the back face is arranged to mate with coupling formations of the communications module.

- 5 Preferably the interface assembly comprises an interface chassis arranged to convey platform stabilization signals and an interface plate which comprises the back face of the interface assembly, wherein the interface plate is detachable from the interface assembly for substitution of different interface plates having different communication modules mounted thereto.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

Preferred features, embodiments and variations of the invention may be discerned from the following Detailed Description which provides sufficient information for those skilled in the art to perform the invention. The Detailed
15 Description is not to be regarded as limiting the scope of the preceding Summary of the Invention in any way. The Detailed Description will make reference to a number of drawings as follows:

Figures 1 and 2 are top plan and side views of a prior art terrestrial
20 communications link implemented by opposed link ends comprising aligned directional antennas and associated transceivers.

Figure 3A is an exploded view of a link end including a gimbal and actuators for redirecting an antenna thereof according to a preferred embodiment of the
25 present invention.

Figure 3AA shows a detailed view of area "A" of Figure 3A wherein the antenna horn connects to the antenna reflector and associated antenna feed system for coupling signals to and from the radio and pointing system
30 electronics

Figure 3B is a view of how the stabilised platform can be attached to a post of a tower .

Figure 3C is a detailed front view of the antenna system and gimbal.

5

Figure 3D is a detailed rear view of the gimbal and antenna.

Figure 3E is an exploded view of the gimbal and antenna.

10 Figures 4A to 4D are block diagrams of a redirection motion control system according to a preferred embodiment of the invention which comprises a portion of the link end of Figure 2.

15 Figure 4AA is a block diagram of a generic feedback control loop having position and velocity loops.

Figure 4E shows the two ends of a digital communications link, for the case of a proximate beacon transmitter at each end that transmits the wide beamwidth beacon signal to the other end.

20

Figure 4F shows the two ends of a digital communications link, for the case of a coincident beacon transmitter at each end.

25 Figures 5 to 8 illustrate a terrestrial link implemented by opposed link ends according to the preferred embodiment of the present invention in operation.

Figure 9, illustrates a terrestrial communications link according to a further embodiment of the invention wherein the link ends track a common wide beamwidth beacon transmitter that is located a distance off from a line between the two link ends.

30

Figure 10 is a cross sectional view of an interface assembly, according to a preferred embodiment of the present invention, mounted to a piece of generic

radio communications equipment, i.e. a radio frequency data transceiver module.

Figure 11 is a non-cross sectional view corresponding to figure 10.

5

Figure 12 is a view of a front face, i.e. the stabilization side face, of the interface plate of the interface assembly of Figures 10 and 11.

Figure 12A is a view of a back face of an interface plate of the interface
10 assembly of figures 10 and 11.

Figure 13 is a stylized diagram showing the interface assembly in use coupling a piece of communications equipment to a stabilization assembly.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

20 Referring now to Figures 3A to 3E, there is depicted an antenna assembly or "link end" 100 according to a preferred embodiment of the present invention. As will be explained, the link end 100 includes a redirecting assembly in the form of a two axis gimbal 3 that has x and y pivots 104, 106. One side of the gimbal 3 comprises a gimbal platform 109 that is fastened to a support post
25 80 which forms part of a support structure such as a radio communications tower. An opposite side of the gimbal includes an antenna support 107 to which an antenna assembly 108 is mounted. The antenna assembly 108 includes an antenna feed 5, sub-reflector 7a and reflector 7. The reflector 7 comprises a directional antenna. Actuators in the form of controllable motors
30 4b and 4d (shown schematically in Figure 4C) are built inside the pivot points 104 and 106 to cause the portions of the gimbal that are pivotally interconnected to swing about the pivots. Accordingly, since the gimbal platform 109 is held fast with the support post, the pointing direction of the

antenna support 107, and hence the antenna assembly 108 mounted thereto, can be pivoted about the axes of the x and y pivots relative to the platform mounting plate 109.

- 5 A shroud 2 is provided that is fast with the gimbal platform 109 and a radome 1 is fastened to the shroud

The present example, which is illustrated in Figures 3A-3B and 4A - 4D, has been designed to meet the following requirements:

10

Pointing error	< 0.05 degrees (more generally, about 0.25 of the beamwidth)
Acquisition range	> 7 degrees
Tracking fade margin	> link fade margin
degradation of E-band link performance	Minimal
Short acquisition time	10's of seconds
Wind speeds	> 100 km/hour

The relevant parameters of a support tower to which the link end 100 of Figures 3A to 3E is mounted are assumed to be as follows:

15

- Oscillations are likely to be less than 2 Hertz
- Tilt and twist are likely to be less than 2 degrees (except for monopole towers)
- Monopole towers can develop larger tilts (e.g. 6 degrees).

20

The internal components of the link end 100, including actuators in the form of gimbal elevation and azimuth motors 4b and 4d (Figure 4C) and associated control circuitry 22 (Figure 4C), are completely enclosed by the radome 1 and shroud 2. The radome 1 and shroud 2 help to reduce wind loading on the antenna assembly 108 and so allow the use of actuators in the form of the

25

relatively low-torque, direct drive motors 4b, 4d which are mounted inside the pivots 104 and 106. The use of direct drive motors eliminates mechanical backlash, which would otherwise make it difficult to meet the $\frac{1}{4}$ of beamwidth (e.g. 50 milli-degree) pointing requirement. Complete enclosure of the internal components by the radome 1 and shroud 2 also provides protection from rain, hail and ice build-up.

While the redirecting assembly comprises a two axis gimbal 3 in the presently described preferred embodiment, the redirecting assembly might be otherwise. For example, while far less practical the redirecting assembly might include a tripod with independently actuated telescopic legs for providing tilting of the directional antenna.

Figures 4A to 4D comprise a block diagram of the beacon sensing and control processing circuitry of the link end 100. In the presently described preferred embodiment of the invention, some of the control processing circuitry of Figures 4A to 4D is included within the radome 1 and shroud 2 of Figure 3, and some is mounted directly behind. However, it will be realised that in other embodiments the electronic control circuitry might be housed at a separate location.

More specifically, Figures 4A to 4D depict one end (the "near-end") of a terrestrial link, for example a link similar to link 120 (Figure 4E) that communicates with a second identical system at the "remote-end". Optimum performance is achieved between the two ends when the antenna assemblies at both ends point directly at each other so that they maximise the corresponding received E-band data signal strength at both ends.

The antenna assembly 108 comprising the main reflector 7, 7-horn antenna feed 5, and sub-reflector 7a operates to transmit and receive a main data signal (at E-band in this instance) to and from the remote end, and to receive a beacon signal (in the implementation of Figure 4E or 4F), while the gimbal 3 is driven by motors 4b, 4d to cause pivoting about pivots 104, 106 and so

steer the antenna assembly 108 to maintain optimum pointing to the remote end, by compensating for relative motion between the ends. The E-band signal is received and delivered from and to the antenna assembly 108 by an E-band feed assembly 110 (Figure 3AA and 4D). The E-band feed assembly
5 110 also generates an E-band monopulse difference signal in the elevation plane, by sensing the signal across two slots 110a, 110b in the horn symmetrically placed in the elevation axis on either side of the main E-band input 112 at the center of the feed.

10 Coincident with the boresight of the feed 5 is a K-band feed sub assembly 114 (figure 3AA and 4D). Using pairs of slots 114a, 114b, 114c, 114d on either side of the main E-band boresight 112, the K-band feed sub-assembly 114 generates a sum signal as well as difference signals in both the elevation and azimuthal planes from the received beacon signal that is transmitted from the
15 far end K-band beacon transmitter. The K-band feed sub assembly 114 can also be used to transmit a narrow-beam K-band beacon signal towards the far end.

Beacon transmitter signals at the near end are generated by two K-band
20 beacon oscillators 8a (Figure 4D) and 8b (Figure 4B) operating at slightly different frequencies, phase locked to a 100 MHz reference signal. Output from the first beacon oscillator 8a is fed to a small, wide beam-width beacon antenna 6 that is used only for transmitting a beacon signal. The transmit beacon antenna 6, is, in the present embodiment, is proximate with the
25 antenna assembly 108. In other embodiments the transmit beacon antenna 6 may be a considerable distance away from the antenna assembly 108. In that case the remote end receiver firmware may need to include instructions for the remote link end to take into account the directional offset between the transmit beacon antenna position and the position of the main (E-band) data
30 transmitter direction. Because of its wide beam width, it is assumed that the transmit beacon antenna 6 will always illuminate the remote end antenna, even when near-end transmitter motion is severe.

In the embodiment of Figure 4D the wideband antenna 6 is mounted to the shroud (which is fixed relative to the tower) whereas in the embodiment of Figure 4E it is mounted to the directional data signal antenna, which corresponds to main reflector 7 of Figure 4D. Both scenarios are feasible
5 because of the wide beamwidth of the beacon antenna 6 however it is preferable to mount it to the shroud so as not to disrupt the main reflector's transmission pattern.

Signal from the second beacon oscillator 8b (Figure 4B) is transmitted through
10 the narrower beam-width K-band feed subassembly 114 that is integrated with the main E-band feed subassembly 110 into antenna feed 5 and is coincident therewith. Because the narrow beam signal from the second beacon oscillator 8b reflects, via sub-reflector 7a off the much larger main reflector 7, it has a much narrower beam-width. The narrower beamwidth reduces the possible
15 range of acquisition angles at the remote end, and may be useful to reduce possible multi-path signal propagation of the beacon causing misleading pointing angles. However, this transmitted beacon signal is therefore more sensitive to near-end tower motion, so may not always illuminate the remote end. The choice of which beacon signal to use for tracking – narrow beam or
20 wide beam - is made in the antenna control board 23 in accordance with the instructions comprising firmware stored in the electronic memory on that board.

The main E-band data signal is processed in the standard way through an E-
25 band transceiver 9 (Figure 4A). On the receive side, the RF signal is amplified in the transceiver and downconverted before passing to the modem that detects the digital modulation and sends the received data stream externally via a User Data Interface 10 such as an Ethernet fibre optic interface. On transmit, the transceiver 9 modulates the incoming data stream onto an IF
30 signal in the modem, which is then upconverted, linearised, and amplified prior to transmission via antenna assembly 108. The same modem also sends and receives data from the User Management Interface 11 that can be passed

along the link to provide an indication of near end pointing status and other control information useful for network operations.

The K-band beacon receiver feed 114 (Figure 4D) is coincident with the bore-sight of the E-band data feed 112. It is straightforward to combine the E-band horn and the K-band receiver antenna into a single waveguide horn 5, by incorporating a few extra slots and couplers into the main feed. The received K-band monopulse sum and difference signals are downconverted in phase matched downconvertors 12 (Figure 4B). These K-band downconverter channels receive the RF signals from the antenna feed 114 and in the standard way downconvert the received signal to a second IF frequency of 10.7MHz where they are digitised by A/D convertors 13 (Figure 4A) on the Interface board. The downconversion circuitry (Figure 4B) implements the standard functions of band pass filtering (BPF), low noise amplification (LNA), downconverting (DC) to a first IF of 1450 MHz in a mixer phase locked to a 100MHz reference source, and final low pass filtering (LPF). The K-band sum channel includes a directional coupler 24 (Figure 4B) in its path prior to the first band pass filter 116, since the beacon sum port on the narrow beam antenna feed 114 is also used to transmit the beacon as well as to receive it. The difference channels include a switch 118 after the low noise amplifiers 120 since the processing of the azimuth and elevation beacon signals are identical, so the analog hardware can be time shared to save costs.

The received signal tracking information from the E-band monopulse downconversion module 21 and the K-band monopulse downconversion module 12 is passed through analog to digital converters 13 and then processed by microprocessor 14 (Figure 4A) and FPGA 15 (Figure 4A). The FPGA 18 implements a motion control system and outputs a monopulse pointing error vector signal on line 84. The vector signal indicates the deviation in elevation and azimuth from true bore-sight. When a required change in position is indicated by the monopulse tracking information on lines 72, 74, 76, the motors 4b, 4d are driven in both azimuth and elevation by the motor control board 22. The motor control board 22 operates in response to

the monopulse pointing error vector signal from the motion control system 18, until the measured error vector is reduced to zero.

The gimbal control circuitry 22a contains gyroscopes 16a, 16b, which are oriented along the axes of the two pivots 104, 106, to sense the overall motion of the near end antenna. Such motion may be intentional due to the motors, or due to external effects such as wind or temperature. Signals from the gyroscopes 16a, 16b are sensed in an interface board 17 and fed back to motion control system 18 on line 82 (Figure 4A) for use in a feedback system, implemented in the firmware executed by microprocessor 14 and FPGA 18, to correct for unwanted motion. Similarly, the inclinometer 19 provides current elevation angle information, and this can be used upon system initiation, or to provide additional data if multipath or other unwanted signal effects are suspected of corrupting the monopulse tracking data.

The instructions comprising the firmware in memory 20 that is used to process the monopulse data and sensor data, implement both a velocity and position loop. User adjustments and the current state of the microprocessor can be controlled through a User Management Interface 11 such as Ethernet. The firmware and data are loaded into the FPGA and microprocessor from flash memory 20, and stored locally.

To achieve higher pointing accuracy once the main signal has been acquired and the antennas of the near and remote link ends are pointing close to bore-sight, the firmware may include instructions for the narrower beam width of the received E-band signal to be used independently of the beacon signals to provide pointing information for fine-tuning. The E-band signal can more accurately track the main signal propagation axis because it has very narrow beam width, due to its high frequency and the large size of the main reflector

For simplicity, only directional information from the elevation axis is shown in the processing of Figures 4A to 4D. A narrowband E-band beacon signal

generator 9a provided within transceiver 9 to produce a narrowband E-band beacon signal as a separate channel within the main E-band data signal for transmission to the remote end. The narrowband E-band beacon signal from the generator 9a is coupled into the same transceiver 9 and feed system 5 as the main data signal itself. At the near end, a received E-band beacon monopulse difference signal is generated in the elevation plane by the slots 110a, 110b at the antenna horn 5. This is processed by the monopulse E-band feed network 21 (Figure 4B), which is a standard RF down-converter chain consisting of standard RF blocks tuned to the E-band beacon frequency to provide signal filtering, low noise amplification, dual downconversion, and final filtering at a second IF frequency of 10.7MHz. The main E-band data signal is coupled from the E-band transceiver 9 and provides the equivalent monopulse "sum" signal.

Together, the E-band "sum" and "difference" monopulse signals are processed in the FPGA fabric 15 to generate a pointing error signal on line 84 that is derived from the E-band propagation path. The absence of a phase reference on the monopulse sum port requires the antenna to be mechanically scanned either up or down to ascertain the desired direction of movement. The E-band propagation path is the more important data-bearing path, but because of its narrow beam width and susceptibility to path loss, is often difficult or impossible to detect without a more robust and broader beam width K-band beacon signal to first acquire the remote end. This assumes that the K-band and E-band propagation paths are essentially identical.

Where necessary, mechanical scanning of the antenna to first acquire the initial beacon signal is performed in accordance with instructions executed by the firmware in memory 20 running in the microprocessor 14. These instructions cause the antenna to move along a grid pattern over the full range of motion of the gimbal 3 until a peak in received signal strength is detected. The inclinometer 19 (Figure 4C) can be used to set the initial elevation angle in the search. Once the beacon is detected, mechanical scanning ceases and the K-band beacon and ultimately E-band beacon monopulse tracking are

used to accurately point the system. The hardware illustrated in Figures 4A to 4D executes a firmware product that is stored in a memory 20 accessible to (or onboard) the microprocessor 14 and field programmable gate array (FPGA) 15.

5

To reiterate, the instructions coded into the firmware enable the microprocessor and FPGA to implement the redirection procedures that are described herein according to preferred embodiments of the present invention.

10

The commands to drive the motors 4b, 4d are issued through the motion control system 18 (Figure 4A) to the motor and encoder board 22 (Figure 4C). Feedback on movement and acceleration is again provided from the gyroscope sensors 16a, 16b, and on actual position from the position encoders 4a, 4c, through the motor and encoder board 22.

15

Each axis control for the gimbal 3 has a tightly integrated motor 4b, 4d, encoder 4a, 4c and MEMS gyro 16a, 16b. An inclinometer 19 is also included to help with elevation control during acquisition.

20

The control system uses pointing error estimates and the gyros 16a, 16b to keep the antenna 108 pointing directly at the other end of the link. It uses a two-loop configuration. The instructions coded into the firmware that is stored in the digital memory 20 implement a fast inner "velocity" loop, and a slower outer "position" loop which is well known in the industry to be robust. A generic feedback control system using a fast inner velocity loop and a slower outer position loop is illustrated in Figure 4AA.

25

30

The velocity loop is the innermost and fastest of the control loops, having a loop bandwidth of approximately 30 Hz. Its function is to keep the angular velocity of the antenna 108 constant, normally zero. The gyros 16a, 16b are used to sense the actual angular velocity, and the motors 4b, 4d are driven to correct any non-zero angular velocity.

The gyros 16a, 16b cannot be used to maintain pointing indefinitely, as they have small offsets that make their velocity estimate non-zero (but small) when the actual angular velocity is zero. Motion control system 18 estimates the drift over time and applies a bias signal via line 82 to the sensor interface board 17 to cancel the drift.

The position loop's function is to use pointing error estimates to correct for the slow drift of the gyro sensors. The pointing error input for the loop can be derived from any combination of the K-band monopulse signals, the E-band elevation-only monopulse signal, and the encoder signals during the E-band mechanical scan.

The position loop redirects the antenna by applying a non-zero angular velocity demand to the velocity loop. The position loop bandwidth is approximately 2 Hz.

Figure 4E shows the two ends 120a, 120b, of a digital communications link 120 according to a preferred embodiment of an aspect of the present invention. Each end 120a and 120b comprises a link end similar to link end 100 that has been previously described. That is, each link end 120a, 120b has a proximate beacon transmitter that transmits a wide beamwidth beacon signal to the other end, as previously discussed with reference to wide beam beacon antenna 6 of Figure 4D. A separate coincident feed, i.e. a feed such as feed 5 of Figure 4D, illuminates the large data signal antenna reflector to increase antenna gain and generate a second narrow beamwidth beacon signal. This feed uses a combined K-band and E-band horn along a common bore-sight, and is used for transmitting and receiving all E-band signals, for receiving the K-band beacon signal, and for transmitting the second narrow beamwidth K-band beacon signal. The received beacon signal and data link share the same bore-sight.

Figure 4F shows a second embodiment for the two ends of a digital communications link 122, for the case of a coincident beacon transmitter at each end. The antenna feed uses a combined K-band and E-band horn, of the type previously discussed with reference to Figure 4D along a common bore-sight. As well as transmitting and receiving the E-band data signal, it receives and transmits the K-band signal beacon. The wide beamwidth beacon is generated by under illuminating the large reflector at the K-band beacon frequency, reducing the antenna gain. The narrow beamwidth beacon is generated by fully illuminating the large reflector at the beacon frequency, increasing the antenna gain. The received beacon signal and data link share the same bore-sight.

The exemplary link end 100 that has been described is programmed to provide at least three methods of directing the antenna assembly 108, which will be explained. The use of the three methods is intended to cover all contingencies; it will be realised that not all, or any, of the three methods need be implemented in every embodiment of the invention.

In the following description various specific preferred frequency ranges and system parameters are mentioned. It will be realised that the invention is not limited to implementations which make use of these specific frequency ranges and system parameters since other values may be used in other embodiments of the invention as circumstances dictate.

The three exemplary methods, which are discussed for purposes of illustrating specific embodiments of the invention are:

1. Monopulse tracking using a beacon frequency at 24 GHz
2. Mechanical scan at 80 GHz (assisted by gyros and 24 GHz monopulse)
3. Elevation-only monopulse at 80 GHz

METHOD 1: 24 GHz Monopulse, 4-horn

The primary tracking method is monopulse tracking at 24 GHz.

Monopulse provides accurate tracking by generating and tracking on a sharp notch in the antenna pattern. The receive signals from four 24GHz feeds are
5 combined to form three antenna patterns. Adding (combining in phase) the four feeds produces a sum pattern. Subtracting the left and right-hand feeds produces an azimuth difference pattern. The elevation difference pattern is formed by subtracting the upper and lower feeds. The pointing error magnitude is calculated by taking the ratio of signal amplitudes on the
10 difference and sum port. The direction of the pointing error can be calculated from the relative phases of the sum and difference signals.

Monopulse tracking is known in the prior art in relation to radar systems and has proven to be robust. Its inherent insensitivity to amplitude variation is
15 beneficial because it allows one end of the link to track the other end, without being affected by level variations caused by pointing changes at the remote end.

Ideally, monopulse tracking would be operated in the E-band so that the
20 tracking is performed along the same propagation path as the main communications signal. However manufacturing tolerances make it very difficult to develop an E-band monopulse feed that provides accurate tracking, in both elevation and azimuth, without degrading the communications channel. For this reason it is preferred that the monopulse tracking operates
25 in the license-free 24 GHz band in the presently described exemplary embodiment.

Monopulse operation requires a signal from the far end to track. Each end of the link radiates a CW "beacon" for the other end to track. Use of a CW
30 beacon allows for large amounts of noise rejection (narrowband digital filtering in the receiver), and also can provide good rejection of interference signals from wide bandwidth digital communications systems. Interference between

links can be avoided by following a beacon band plan, which assigns different beacon frequencies to links in the vicinity of each other.

5 The link end according to this embodiment is designed to transmit two 24 GHz beacons; one on a separate wide beamwidth antenna; and one (at a slightly offset frequency from the first) using the full 1200 mm aperture of the data antenna reflector (~ 0.8 degree beam width). The wide beamwidth antenna is used to assist with acquisition (called Wide Beam Tracking). Once tracking has been acquired, the narrow beam beacon is used to reduce possible
10 effects from multipath (called Narrow Beam Tracking).

The monopulse operation method is as follows:

1. The second antenna adjusts its pointing alignment with respect to the
15 incoming beacon signal from the first antenna to adjust for changes in the angular orientation of the second antenna caused by tower movement of the second antenna.
2. The first antenna adjusts its pointing alignment with respect to the incoming
20 beacon signal from the second antenna to adjust for changes in the angular orientation of the first antenna caused by tower movement of the first antenna.
3. The second antenna also adjusts its pointing alignment with respect to the incoming beacon signal from the first antenna due to path propagation
25 changes between the two antennas.
4. The first antenna also adjusts its pointing alignment with respect to the incoming beacon signal from the second antenna due to path propagation changes between the two antennas.
- 30 5. Each antenna acts independently of the other with respect to these angular adjustments and the rate of change of angular adjustment and associated time delays are adjusted such that the antennas do not lock into a "hunting

mode" which would then drive the angular motions. The antennas respond to angular movements caused by external factors- they are configured not to mutually generate their own or amplify the externally applied angular movements

5

METHOD 2: Coordinated Mechanical Scans with gyro assist

Mechanical scanning (with gyro assist) can be used in those cases where "perfect" 24 GHz pointing is not perfect at E-band frequencies. This may occur in some atmospheric conditions in which beam bending can cause path divergence between the 24 GHz and E-band signals.

The mechanical scan method introduces very small periodic perturbations in the antenna pointing direction. The variations in received signal level of either or both of the beacon and/or the E-band communications signal, during the perturbations, are analysed to estimate the pointing error. The rate at which new estimates of pointing error can be provided is relatively low, as the antenna must be physically moved to produce the pointing perturbations. The pointing error update rate is approximately 1 Hz. Gyros are used to maintain pointing whilst in the mechanical scan mode. New pointing estimates are averaged over time to correct for gyro drift.

Coordination between ends is required in mechanical scan mode. This is because perturbations at the other end of the link will introduce amplitude changes that are indistinguishable from local perturbations in pointing direction. Coordination can be achieved via signalling on the beacon (changing frequency) or through use of GPS derived clocks at both ends of the link.

METHOD 3: E-band elevation-only monopulse

An elevation-only, E-band monopulse feed may be included to check whether "fine-tuning" in the elevation plane is necessary to account for possible

differences in propagation between 24 GHz and E-band frequencies due to path bending.

5 The E-band monopulse feed uses two small rectangular apertures to produce an elevation null, and will be used to ensure the antenna is correctly positioned in the elevation plane at E-band (in case the 24 GHz monopulse generates misleading pointing information due to e.g. ducting or multipath causing different propagation paths).

10 Referring now to Figures 5A and 5B, in use the ends of the link 126a, 126b are initially powered up. Each end then executes firmware stored in memory accessible to its Microprocessor + FPGA (Figure 4A) to proceed through the following steps:

15 ***Open Loop Pointing Mode***

- I. Set elevation based on inclinometer.
- II. Set azimuth based on last used value from azimuth encoder 4C
- III. Check/adjust gyro 16a, 16b calibration
- 20 IV. Mechanically scan until wide beam beacon is detected
- V. Jump to wide beam tracking mode

Referring now to Figures 6A, 6B, once the wide beamwidth beacon has been detected the system then proceeds to 24 GHz wide beam tracking mode in
25 which it proceeds through the following steps:

24 GHz Wide Beam Tracking Mode

- 30 1. Use monopulse to track the wide beamwidth beacon
2. Listen for narrow beamwidth beacon
3. Jump to narrow beam tracking mode
4. If wide beam beacon is lost then return to open loop pointing

Referring now to Figures 7A and 7B, if the 24 GHz Wide Beam Tracking Mode ends with the narrow beamwidth beacon being detected then the system proceeds through the following steps:

5

24 GHz Narrow Beam Tracking Mode

- a. Use monopulse to track the narrow beam beacon
- 10 b. Jump to E-band mechanical tracking after successfully tracking for sometime
- c. If wide beam beacon is lost, return to wide beam tracking

Referring now to Figure 8, if the 24 GHz Narrow Beam Tracking Mode ends with successful tracking on the narrow beamwidth beacon then the system proceeds through the following steps:

15

E-band mechanical tracking mode

- 20 I. Periodically perturb pointing to confirm E-band pointing
- II. If required adjust pointing to follow E-band signal
- III. If E-band lost then return to narrow beam tracking

E-band elevation-only monopulse mode

25

When the main communications signal is acquired

- I. Use the E-band monopulse subsystem to continue to track the E-band communications signal
- II. If required, adjust elevation of antenna to follow E-band signal
- 30 III. If signal communications is lost, return to wide beam tracking

Wide Beamwidth Common Beacon Embodiment

Referring now to Figure 9, there is illustrated a terrestrial communications link 150 according to a further embodiment of the invention. In the embodiment of Figure 9 a single wide beamwidth beacon transmitter 152 is provided at a location that is off the line of site between the data antennas 154a, 154b of the link ends 150a, 150b. The beacon 152 could be located terrestrially, for example on a tower or high building, or alternatively it could be a satellite beacon in some situations. Each link end is provided with a beacon receiver antenna 156a, 156b that is either rigidly fastened to the data receiver antenna or electromechanically slaved to it so that at each end the beacon receiver antenna and the data receiver antenna move in concert. For example, the 2-axis gimbal shown in Figure 3A may be arranged to tilt and rotate both the beacon receiver antenna and the data receiver antenna together. The beacon signal from the beacon receiver antenna is processed by circuitry for its link end as shown in Figures 4A to D.

Using the platform with a pre-existing radio apparatus

A preferred embodiment of the previously described stabilized wireless platform requires a monopulse antenna feed structure that senses both the incoming data signal and the direction indicating beacon signal, which typically operates at different frequencies. Thus the antenna feed must receive both signals, and process the beacon frequency to produce both the monopulse sum and difference signals.

The monopulse feed requires three separate connections to extract the direction-indicating signals at the beacon frequency, and a fourth separate connection for the data communications signal itself. Each of these connections has an extremely tight mechanical tolerance to ensure minimum signal leakage between them (which can cause signal corruption), phase matching of the monopulse signals, and environmental integrity.

The beacon signals provide two-dimensional pointing information to the pointing electronics indicating the direction the antenna is currently pointed off

its bore-sight. Using this information, the pointing electronics adjusts the direction of the antenna for optimal signal strength in the data communications channel, through the stabilized platform mechanical system described above.

5 However, in the case of generic, pre-existing E-band radio communications equipment, its pre-existing antenna and antenna feed are neither equipped to generate or sense the beacon pointing signal, nor to provide the appropriate monopulse outputs.

10 Within the radio communications market there are a large number of vendors that manufacture E-band radio communications equipment incapable of dynamically steering the antenna in the desired direction. These vendors include *E-Band*, *Gigabeam*, *Aviat*, *Siae Microelectronic*, *Huawei* and *Alcatel*. This equipment could benefit from using the techniques previously described.

15 It would be advantageous if such communications equipment could be used with a large antenna, which would increase the equipment's useful range or allow its use on less stable towers that would normally require dynamic antenna pointing both of which are highly desirable.

20 It would also be advantageous if it were possible to readily integrate a generic pre-existing piece of communications radio hardware to a system for maintaining alignment of a terrestrial communication link in a straightforward and time efficient manner.

25 An embodiment of a further aspect of the invention will now be described which provides a replacement antenna and antenna feed interface that can be mounted with the pre-existing piece of communications radio hardware on a stabilized platform. As previously described herein, the stabilized platform includes a direction finding beacon receiver and transmitter.

30

Consequently, in a preferred embodiment of the invention there is provided an Interface Chassis that is arranged make the desired electrical and mechanical

interfaces between the generic radio, the replacement antenna and feed, and the stabilized platform.

The replacement antenna and antenna feed are the same as previously described. They provide the necessary integration of the received beacon electromagnetic signal with the E-band data communication signals, and importantly, permit the direction finding beacon signal to be fed through the new Interface Chassis between the antenna and the radio, into the electronic control system for the stabilised platform, where the desired pointing direction is calculated, while transparently passing through the E-band signal to the radio transceiver.

This facilitates the full benefits of the previously described stabilization techniques for any generic E-band equipment.

In a preferred embodiment of the present invention, the feed of the stabilization system is designed so that it may be simply and efficiently disconnected in the field. This is advantageous in order to implement repairs in practical use.

Within the preferred embodiment previously described, for example with reference to Figures 3A to 4D, the module that is mounted on the antenna feed interface is a combined E band communications and pointing chassis, with integrated pointing and data elements. This presents a difficulty if the system is to be used with any third party E band communication system.

Referring now to Figure 10 (which is cross sectional) and Figure 11, there is shown a view of an Interface Assembly 210 according to a preferred embodiment of the invention, in use. Figures 10 and 11 show the entire Interface Assembly 210 with the Interface Chassis 206 and the Interface Plate 204 mounted directly to the pre-existing, generic communications equipment 202. The Interface Assembly 210 comprises an Interface Plate 204 that is mounted to an Interface Chassis 206. The Interface Assembly 210 sits

between the antenna and its monopulse antenna feed, and a piece of generic radio communications equipment 202. The back face 200 of the Interface Plate 204 is arranged to complement the generic radio communications equipment 202. The Interface Chassis 206 fits onto the antenna feed interface, e.g. the interface plate 130 that is shown in Figures 3AA and 4D, directly by attachment of its front plate 208, and splits the monopulse beacon pointing and E-band data communications signals from the combined monopulse beacon/data antenna feed 5 (Figure 4D) as previously described. The Interface Assembly 210 routes the E-band data communications signal transparently from the feed, through the Interface Chassis 206, to the Interface Plate 204 and thence to the third party generic E band communications system 202.

The Interface Chassis 206 also exports the beacon pointing signals from the antenna feed for connection to the pointing electronics of the stabilized platform. This allows its pointing systems to operate to actively steer the antenna via the gimbal 3 and motors 4b, 4d (Figure 4D).

The E-band radio communications hardware is now housed in the generic, pre-existing equipment provided by a third party vendor.

The Interface Assembly 210 also includes the Interface Plate 204 which is mounted on the back face of the Interface Chassis 206. The Interface Plate 204 is provided in different versions, each having an outer face 200 individually tailored to accommodate the bespoke interface requirements of a piece of communications equipment from one or more of each of the alternative E-band data communications equipment manufacturers equipments. Such manufacturers include international vendors such as *Aviat*, *Siae* and *Huawei* for example. It is preferred that the interface plate 204 is removable from the Interface Chassis 206 and replaceable thereto even in the field, to allow alternative equipment manufacturers' systems to be used (even after installation).

Figure 12 shows the inside, i.e. the chassis 206 side of the Interface Plate 204. This plate is suitable to attach to one of several possible alternative manufacturer's equipment, in place of that manufacturer's standard antenna and E-band feed.

5

Figure 13A is a stylized diagram showing the interface assembly in use and including an interface plate 204 coupling a corresponding piece of communications equipment 202 inside a stabilization assembly, e.g. an assembly similar to that shown in Figure 3D, and whose front plate 208
10 attaches to the antenna feed interface, e.g. the interface plate 130. With reference to Figure 13B, the interface plate 204 and the communications equipment 202 may be replaced with any one of the paired interface plates 204a to 204n and communications equipment 202a to 202n. For example, interface plate 204b is formed to have a back face 200 that complements the
15 mounting formations of communications equipment 202b and similarly for the other interface plate and communications equipment pairs.

Although embodiments of the invention have been described with reference to communications at E-band frequencies, it is recognized that the technique is
20 equally applicable to operation at other bands, such as Q-band or V-band, where the very high radio frequency used for the data communications results in narrow beam-widths that may require antenna stabilization to maintain pointing between two antennas at both ends of the communications link.

25 It will be understood that preferred embodiments of the invention provide an interface arrangement that permits the previously described pointing technology to be used with generic communications equipment, allowing such equipment to be used with large antennas or on towers subject to movement.

30 The above description identifies at least one specific, substantial and credible use for the invention.

In compliance with the statute, the invention has been described in language more or less specific to structural or methodical features. The term "comprises" and its variations, such as "comprising" and "comprised of" is used throughout in an inclusive sense and not to the exclusion of any
5 additional features.

It is to be understood that the invention is not limited to specific features shown or described since the means herein described comprises preferred forms of putting the invention into effect. The invention is, therefore, claimed in
10 any of its forms or modifications within the proper scope of the appended claims appropriately interpreted by those skilled in the art.

Throughout the specification and claims (if present), unless the context requires otherwise, the term "substantially" or "about" will be understood to
15 not be limited to the value for the range qualified by the terms.

Any embodiment of the invention is meant to be illustrative only and is not meant to be limiting to the invention. Therefore, it should be appreciated that various other changes and modifications can be made to any embodiment
20 described without departing from the spirit and scope of the invention.

CLAIMS:

1. An apparatus comprising a link end for a terrestrial communications link including:
 - a directional antenna;
 - a redirecting assembly mounted to the directional antenna;
 - one or more actuators coupled to the redirecting assembly;
 - a control system arranged to control the redirecting assembly in response to variations in the strength of a terrestrial beacon signal.
2. An apparatus according to claim 1, including an antenna feed to transmit and receive a main data signal and to receive the beacon signal, the antenna feed including a horn defining a boresight for propagation of the main data signal therealong and second horn parallel thereto to or integrated therewith to receive said beacon signal.
3. An apparatus according to claim 1, including an antenna feed to transmit and receive a main data signal and to receive said beacon signal, the antenna feed including an elongated bore having a boresight for propagation of the main data signal and one or more pairs of slots disposed on either side of the main bore and parallel thereto to receive said beacon signal.
4. An apparatus according to claim 1, wherein the redirecting assembly comprises a two axis gimbal.
5. An apparatus according to claim 4, wherein the control system includes an azimuth control subassembly in communication with a first actuator of said actuators, wherein the first actuator is arranged to vary an azimuth angle of the gimbal.
6. An apparatus according to claim 4, wherein the control system includes an elevation control subassembly in communication with a second actuator of

said actuators, wherein the second actuator is arranged to vary an elevation angle of the gimbal.

7. An apparatus according to claim 6, wherein the elevation control subassembly includes an inclinometer.

8. An apparatus according to claim 5, wherein the azimuth control subassembly includes a first gyroscope arranged to sense angular velocity of the directional antenna.

9. An apparatus according to claim 7, wherein the elevation control subassembly includes a second gyroscope arranged to sense angular velocity of the directional antenna.

10. An apparatus according to claim 8 or claim 9 wherein the control system is arranged to estimate drift of said gyroscope and compensate accordingly.

11. An apparatus according to any one of claims 1 to 10, wherein the control system is arranged to implement a control system including an inner velocity loop and an outer position loop.

12. An apparatus according to any one of claims 1 to 11 including a beacon source.

13. An apparatus according to claim 12 wherein the beacon source comprises a wireless signal generator and a feed or beacon antenna coupled thereto wherein the feed or beacon antenna is arranged to produce a wider beamwidth than the directional antenna.

14. An apparatus according to claim 13, wherein the beacon generator comprises a K-band signal generator.

15. An apparatus according to any one of the preceding claims, wherein the control system includes at least one monopulse network.

16. An apparatus according to any one of claims 1 to 15, including a second antenna non-parallel to the directional antenna and arranged to move in concert therewith;

wherein the control system controls the redirecting assembly in response to variations in the beacon signal as received by the second antenna.

17. A terrestrial data communications wireless link including:

a first link end including a first directional antenna, a first beacon and a first redirecting assembly coupled to the first directional antenna; and

a second link end including a second directional antenna, a second beacon and a second redirecting assembly coupled to the second directional antenna;

wherein the first directional antenna and the second directional antenna are maintained in mutual alignment by the first redirecting assembly redirecting the first directional antenna in response to a signal from the second beacon and the second redirecting assembly redirecting the second directional antenna in response to a signal from the first beacon.

18. A terrestrial data communications wireless link comprising:

a first data traffic directional antenna of a first end of the link;

a second data traffic directional antenna of a second end of the link wherein said first antenna and said second antenna point at each other;

a first beacon signal directional antenna of the first end of the link pointed at a beacon transmitter located off a line between said first and second data traffic antennas;

a second beacon signal directional antenna of the second end of the link pointed at the beacon transmitter;

a first redirecting assembly of the first end of the link arranged to redirect said first data traffic antenna and said first beacon antenna;

a second redirecting assembly of the second end of the link arranged to redirect said second data traffic antenna and said second beacon antenna;

wherein the first data traffic directional antenna and the second data traffic directional antenna are maintained in mutual alignment by the first redirecting assembly operating in response to a signal from said beacon received by the first said beacon antenna, and the second redirecting assembly operating in response to a signal from said beacon received by the second said beacon antenna.

19. A method for maintaining a first antenna in a desired direction including:
redirecting the first antenna in response to variations in a beacon signal received at a location proximate or coincident with the first antenna wherein the beacon signal emanates from a remote beacon.
20. A method according to claim 19, wherein the first antenna is mounted to a redirecting assembly arranged for redirection thereof and the step of redirecting the antenna includes controlling actuators of the redirecting assembly.
21. A method according to claim 20, wherein the redirecting assembly comprises a gimbal having first and second axes.
22. A method according to any one of claims 19 to 21 including narrowing the beacon signal beamwidth, subsequent to acquisition thereof, for improved accuracy in redirecting the first antenna.
23. A method according to any one of claims 19 to 22, wherein the first antenna comprises part of a first end of a terrestrial data communication link and said remote beacon is located proximal or coincident with a second antenna comprising a second end of said communication link.

24. A method according to claim 23, wherein the beacon signal beamwidth is greater than a beamwidth associated with a data communication signal of the second antenna.

25. A method according to claim 23 or claim 24 wherein boresights of the first antenna and its beacon receiver antenna are coincident, the method including:

carrying out the step of redirecting the first antenna in response to the beacon signal until the data communication signal is acquired; and

then redirecting the first antenna in response to variations in the data communication signal.

26. A method according to claim 25, wherein the step of redirecting the first antenna in response to variations in the beacon signal includes applying a monopulse process to thereby improve the accuracy with which the first antenna is redirected.

27. A method according to claim 25 including redirecting the first antenna to mechanically scan for a boresight associated with the beacon signal.

28. A software or firmware product comprising tangible machine readable instructions for execution by an electronic processor for implementing a method according to any one of claims 19 to 27.

29. A method according to claim 24, wherein the beacon signal beamwidth is sufficient to accommodate a range of angular perturbations of the first or second antenna from the desired direction.

30. A method according to claim 19, wherein the beacon signal emanates from a beacon located off the desired direction and wherein the beacon signal is received by a second antenna pointed toward the beacon wherein the second beacon antenna is arranged to move in concert with the first antenna.

31. A method for increasing the operational range of a high frequency wireless data communications module comprising the steps of:

- mounting said communications module to a back face of an interface assembly;

- mounting a front face of the interface assembly to an antenna feed of a platform stabilization assembly to thereby couple the communications module to the antenna feed for receiving and transmitting data signals therefrom;

- wherein the back face of the interface assembly is arranged to mate with coupling formations of the communications module and
- wherein the platform stabilization assembly comprises

- a directional antenna;

- a redirecting assembly mounted to the directional antenna;

- one or more actuators coupled to the redirecting assembly;

- a control system arranged to control the redirecting assembly in response to variations in the strength of a terrestrial beacon signal.

32. A method according to claim 31, wherein the interface assembly comprises an interface chassis and an interface plate which comprises the back face of the interface assembly, wherein the interface plate is detachable from the interface assembly for substitution of different interface plates having different communication modules mounted thereto.

33. A method for mounting any one of a plurality of communications modules to a platform stabilization assembly, wherein each of the communications modules is arranged with a different coupling configuration, the method including:

- producing a plurality of interface assemblies, each of said assemblies having a back face arranged to mate with a corresponding one of the plurality of communications modules and a common front face arranged to mate with the platform stabilisation assembly;

- for a selected one of the communications modules, selecting a corresponding one of the interface assemblies;

mounting the selected communications module to the selected corresponding interface assembly; and
mounting the interface assembly to the platform stabilisation assembly.

34. A method according to claim 33, wherein one or more of the interface assemblies is comprised of an interface plate and an interface chassis for attachment thereto.

35. An apparatus for coupling any one of a number of different communications modules to an antenna feed of a platform stabilization system, the apparatus comprising:

an interface assembly including an interface chassis having a front face arranged to couple to the antenna feed and an interface plate removably fastened to the interface chassis and having a back face arranged to couple to the communications module;

wherein the interface plate is one of a number of interface plates each having a back face arranged to complement various coupling configurations of the different communications modules

36. An interface assembly including:

a back face for coupling to a communications module; and

a front face arranged for coupling to an antenna feed of a platform stabilization assembly to thereby couple said electronic circuitry thereto and to couple the communications module to the antenna feed for receiving and transmitting data signals therefrom;

wherein the back face is arranged to mate with coupling formations of the communications module.

37. An interface assembly according to claim 34 comprising an interface chassis arranged to convey platform stabilization signals and an interface plate which comprises the back face of the interface assembly, wherein the interface plate is detachable from the interface assembly for substitution of different interface plates having different communication modules mounted thereto.

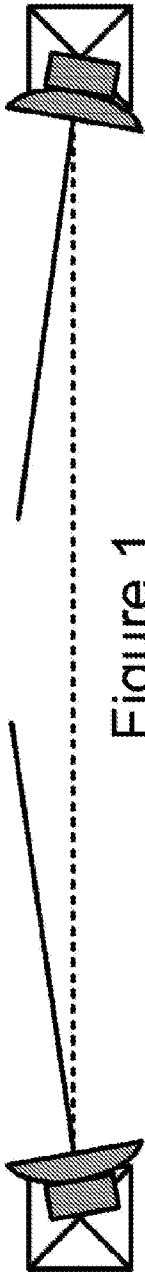


Figure 1
(Prior Art)

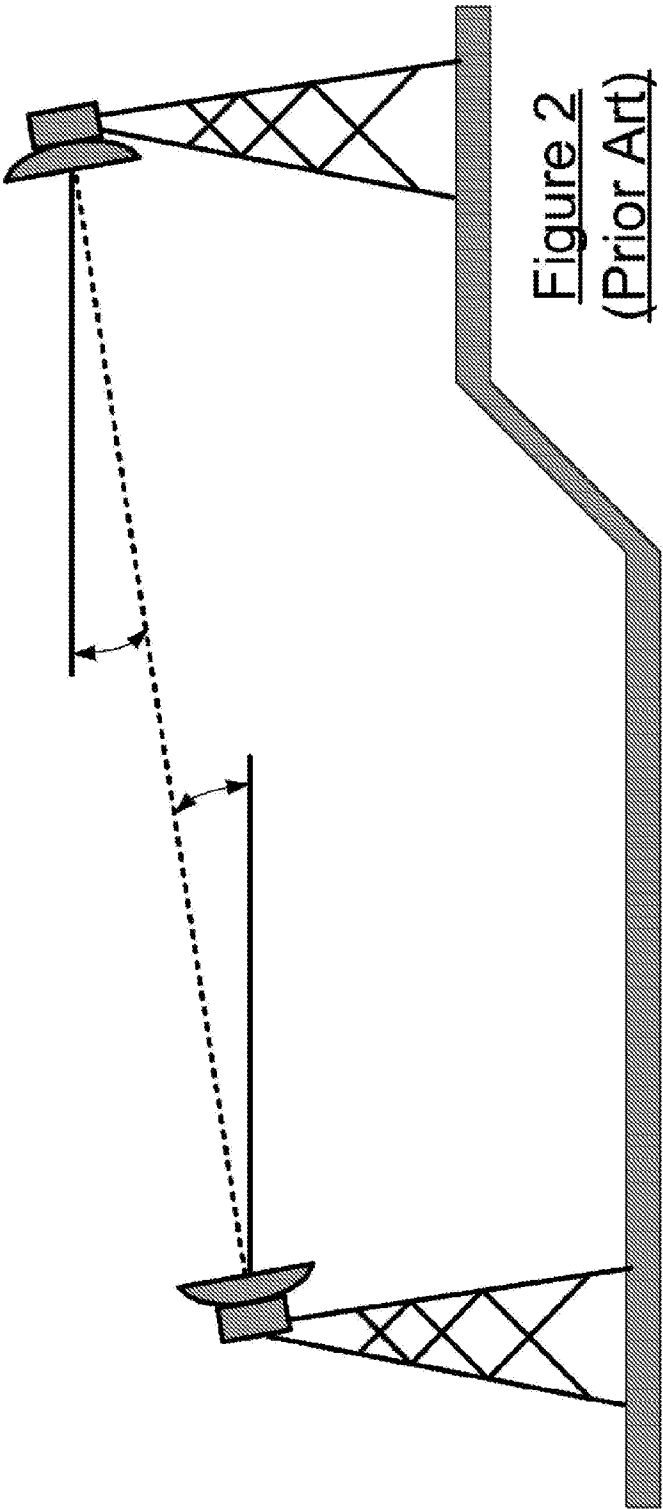


Figure 2
(Prior Art)

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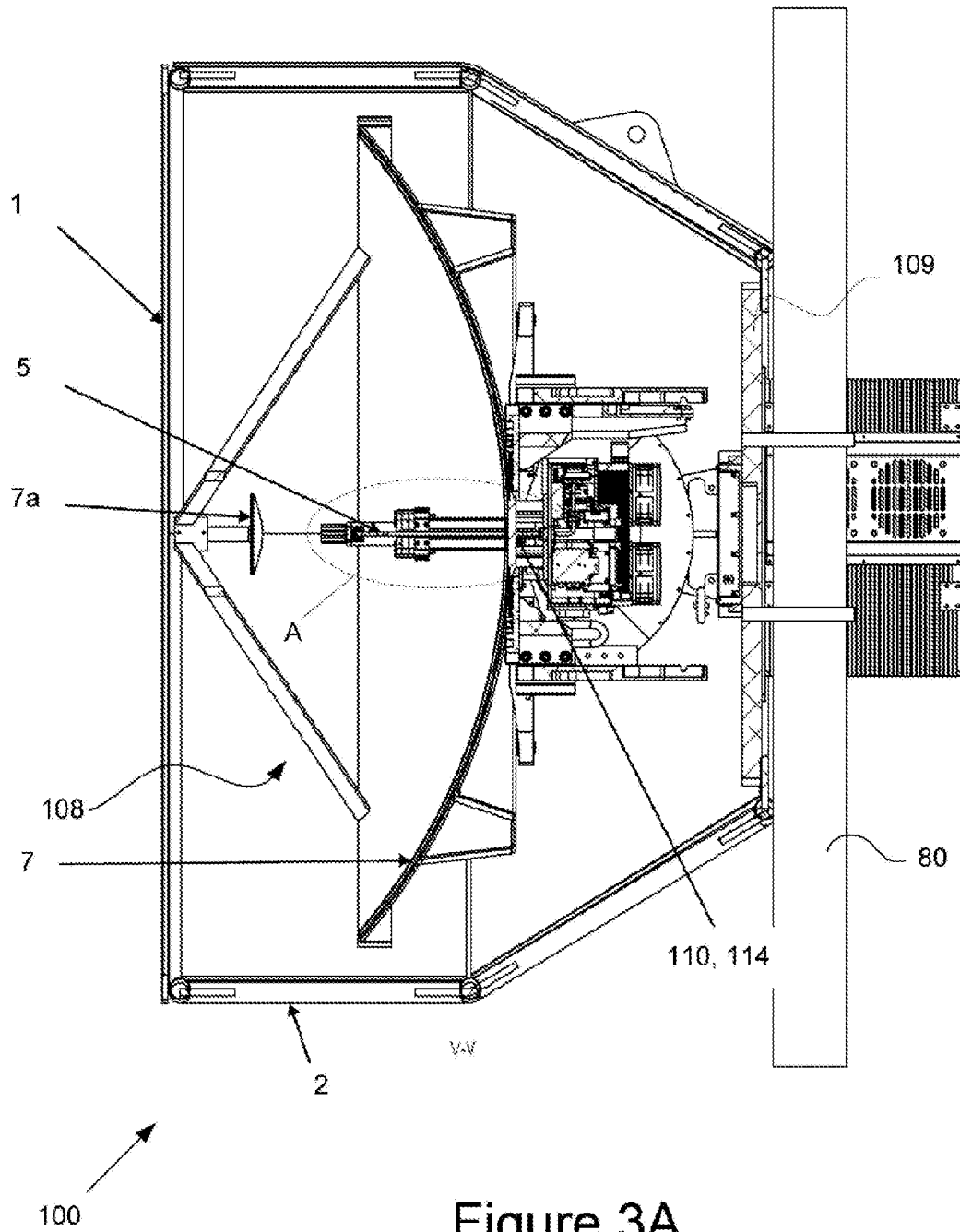


Figure 3A

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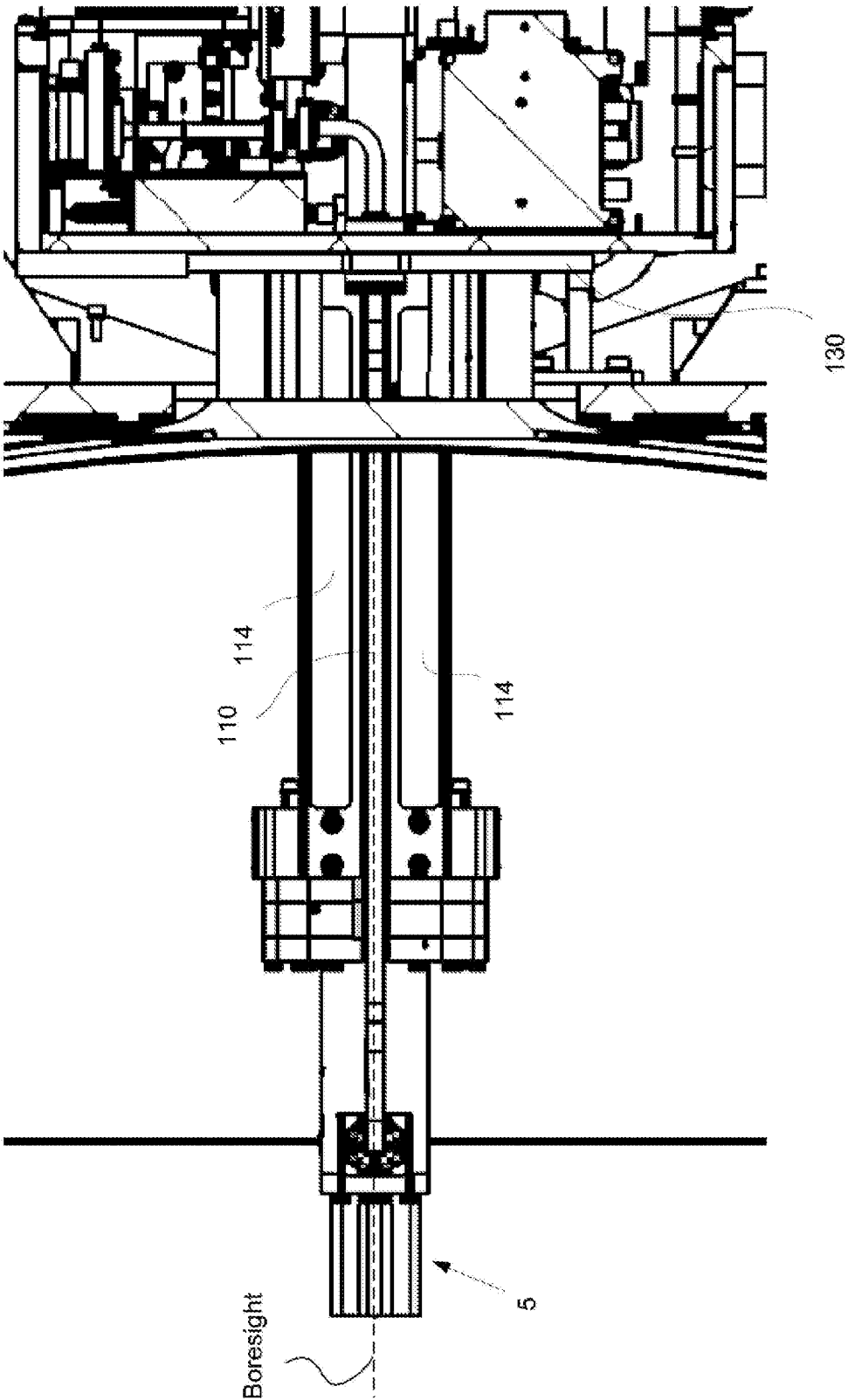


Figure 3AA

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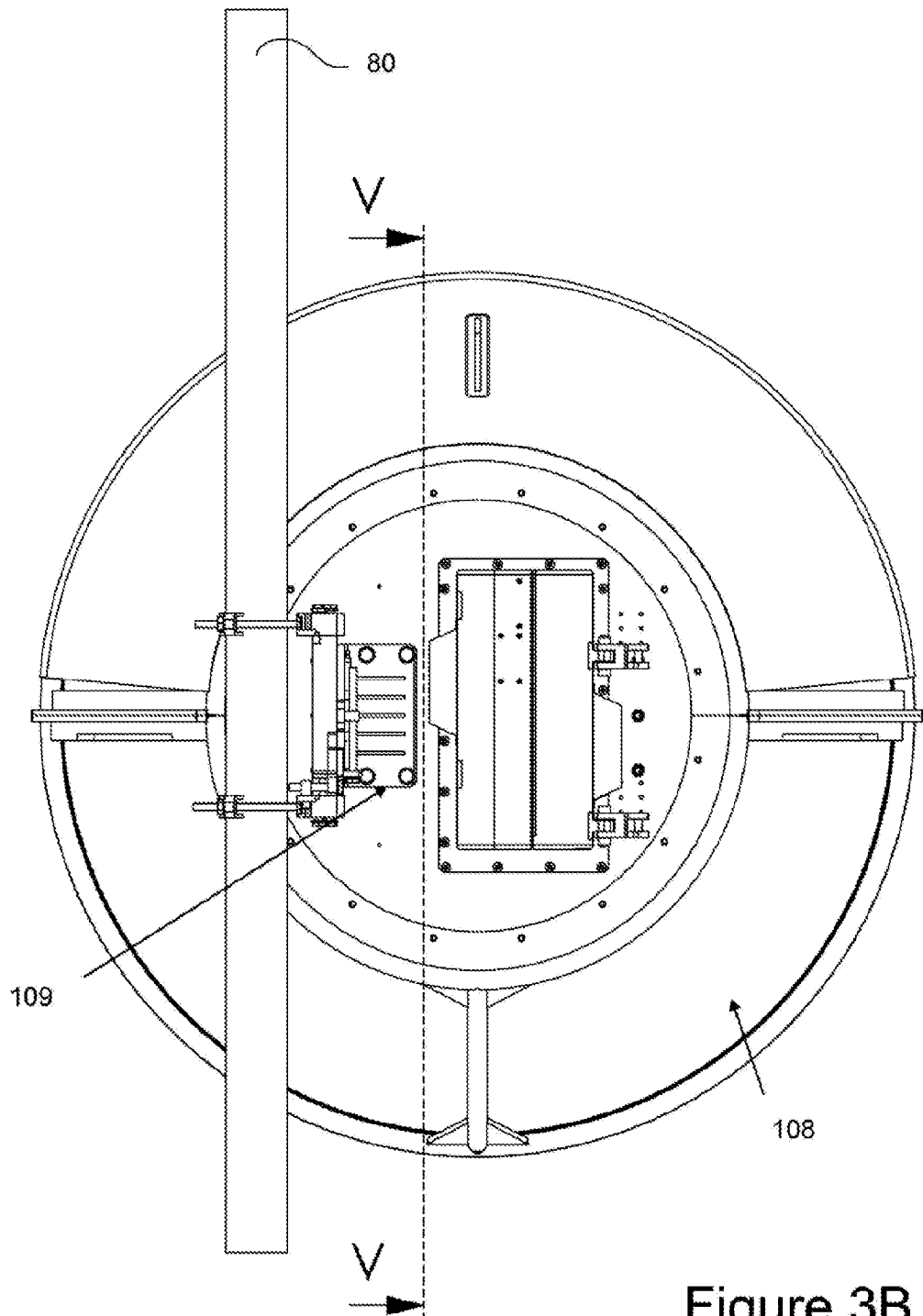


Figure 3B

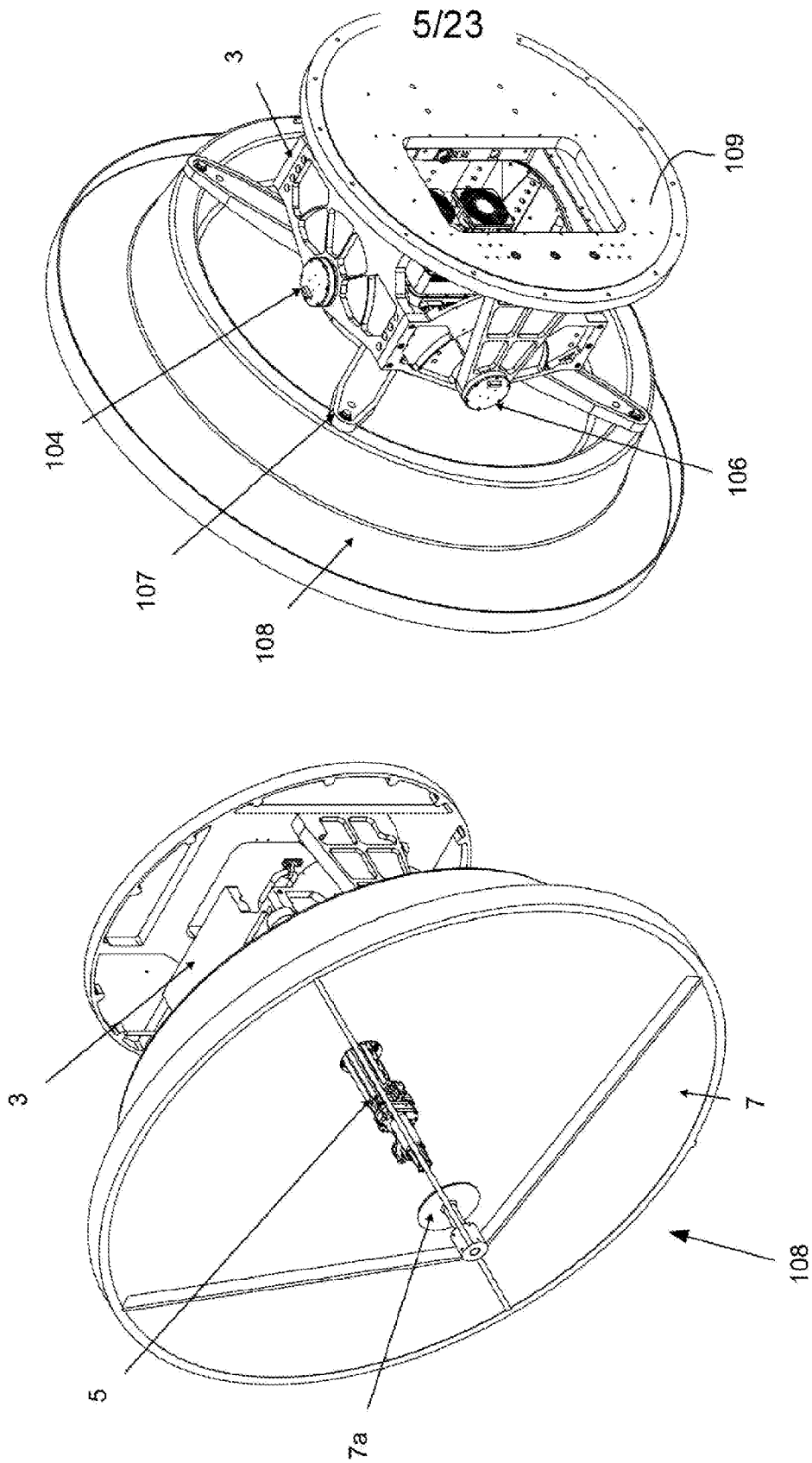


Figure 3D

Figure 3C

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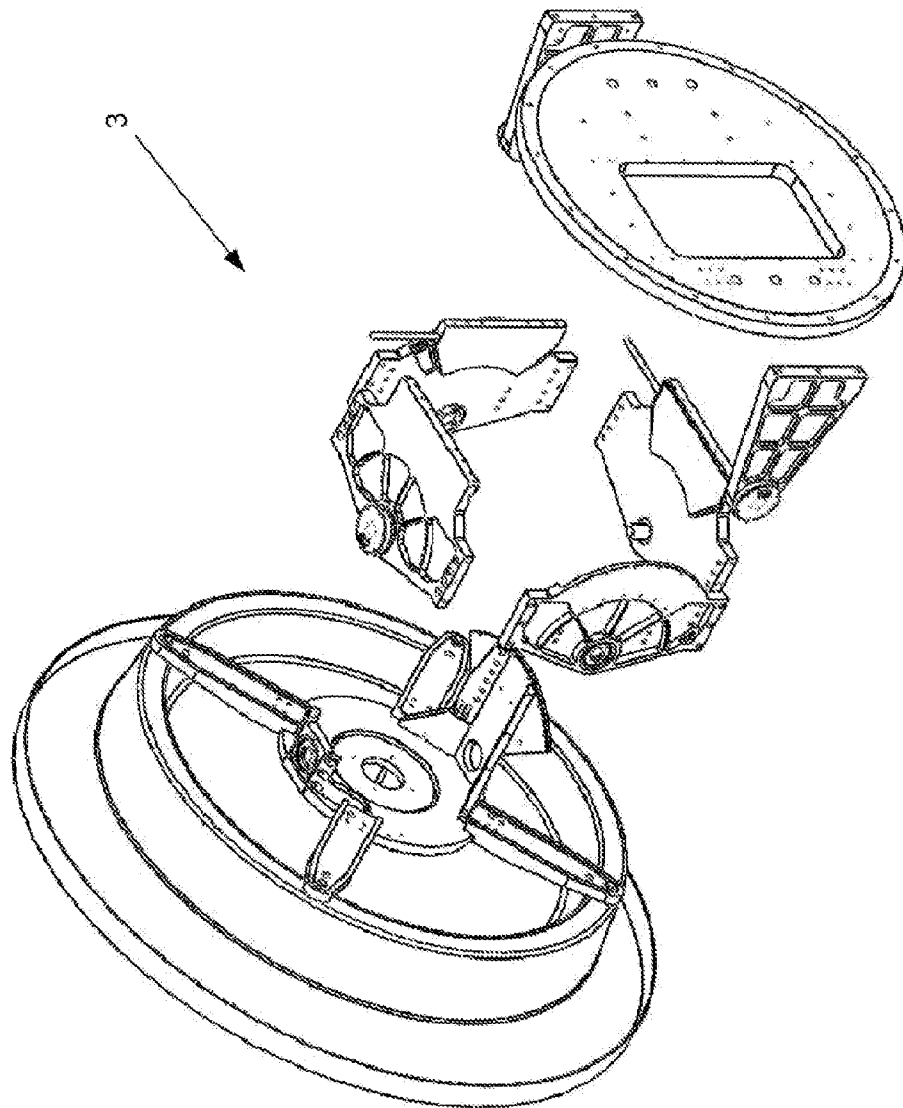


Figure 3E

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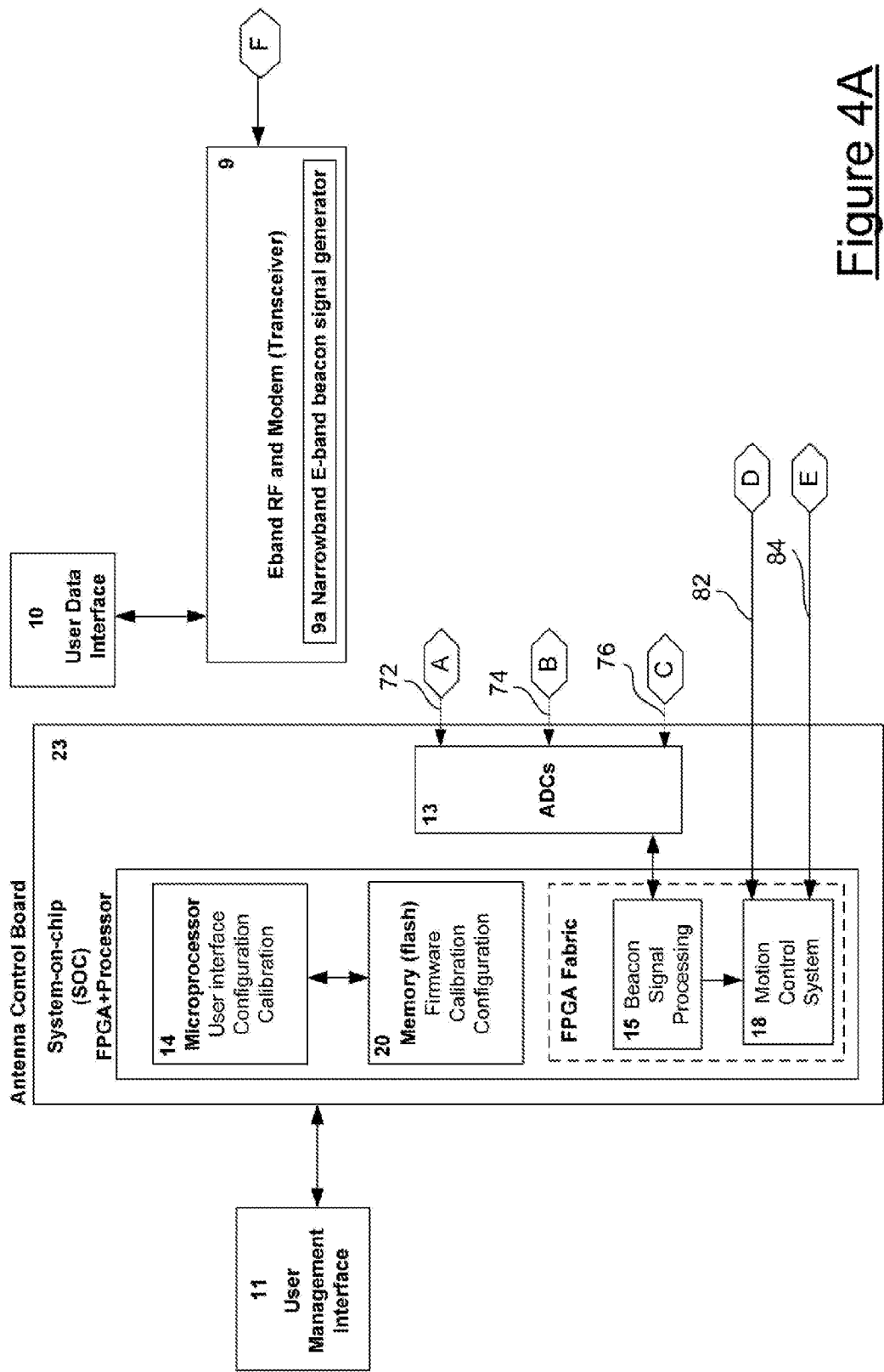


Figure 4A

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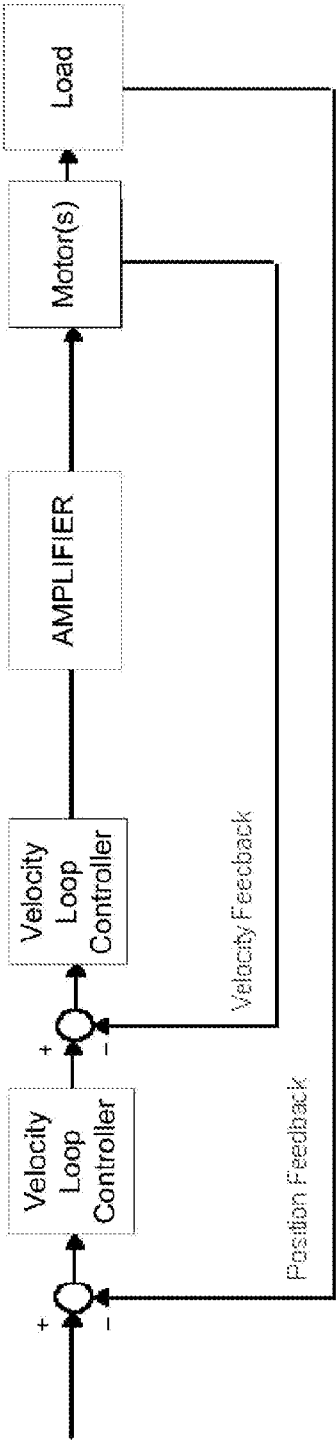
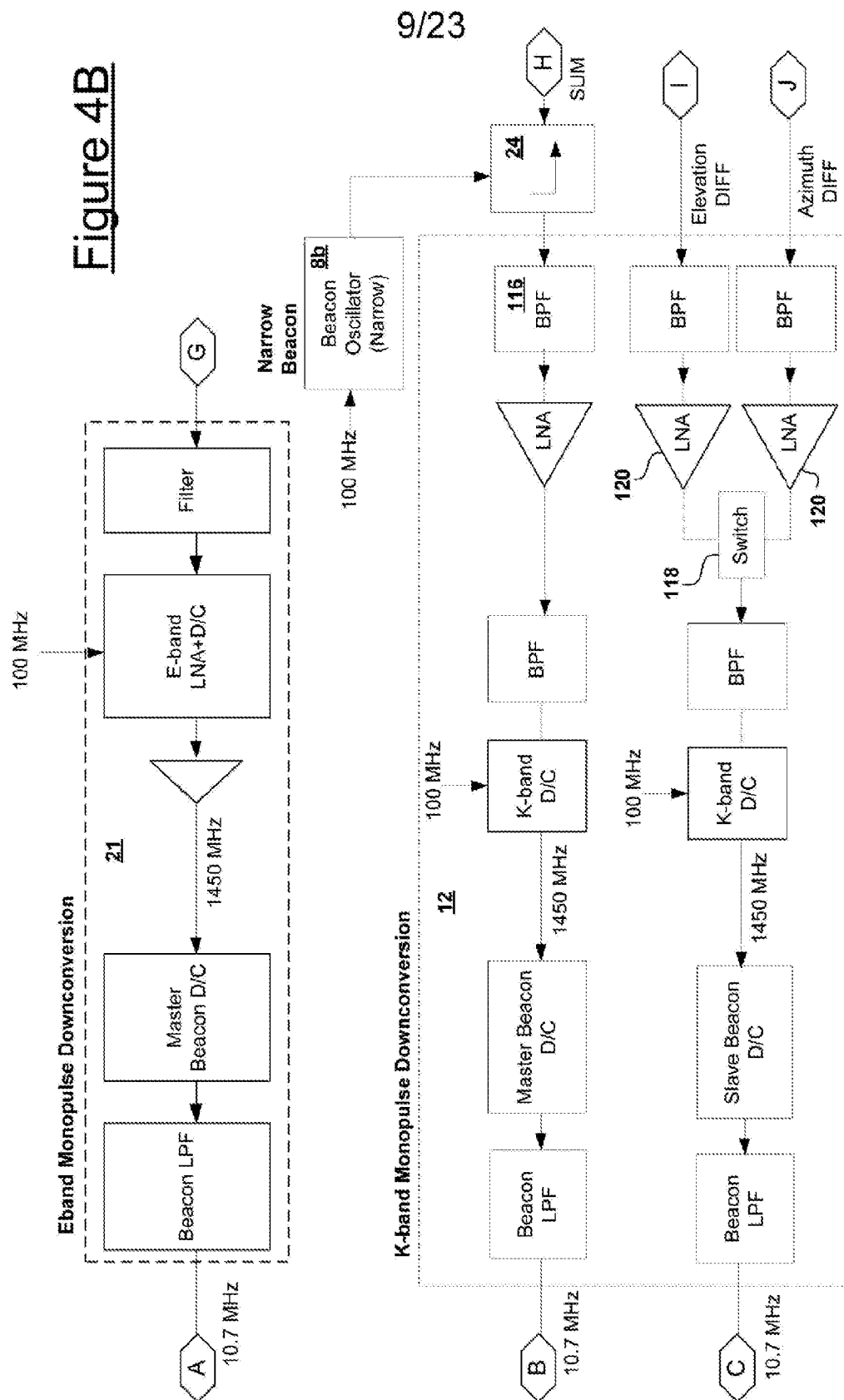


Figure 4AA

Figure 4B



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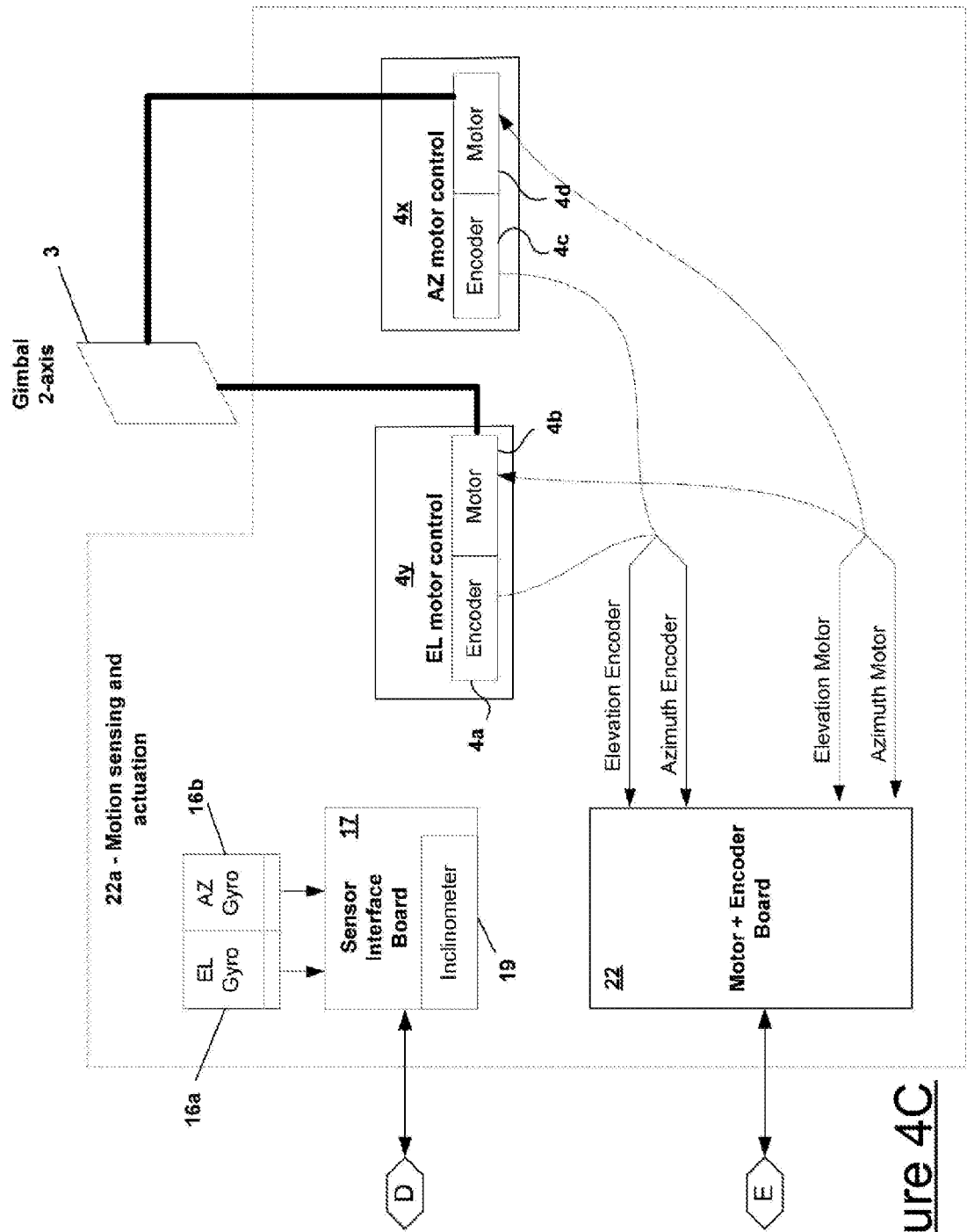


Figure 4C

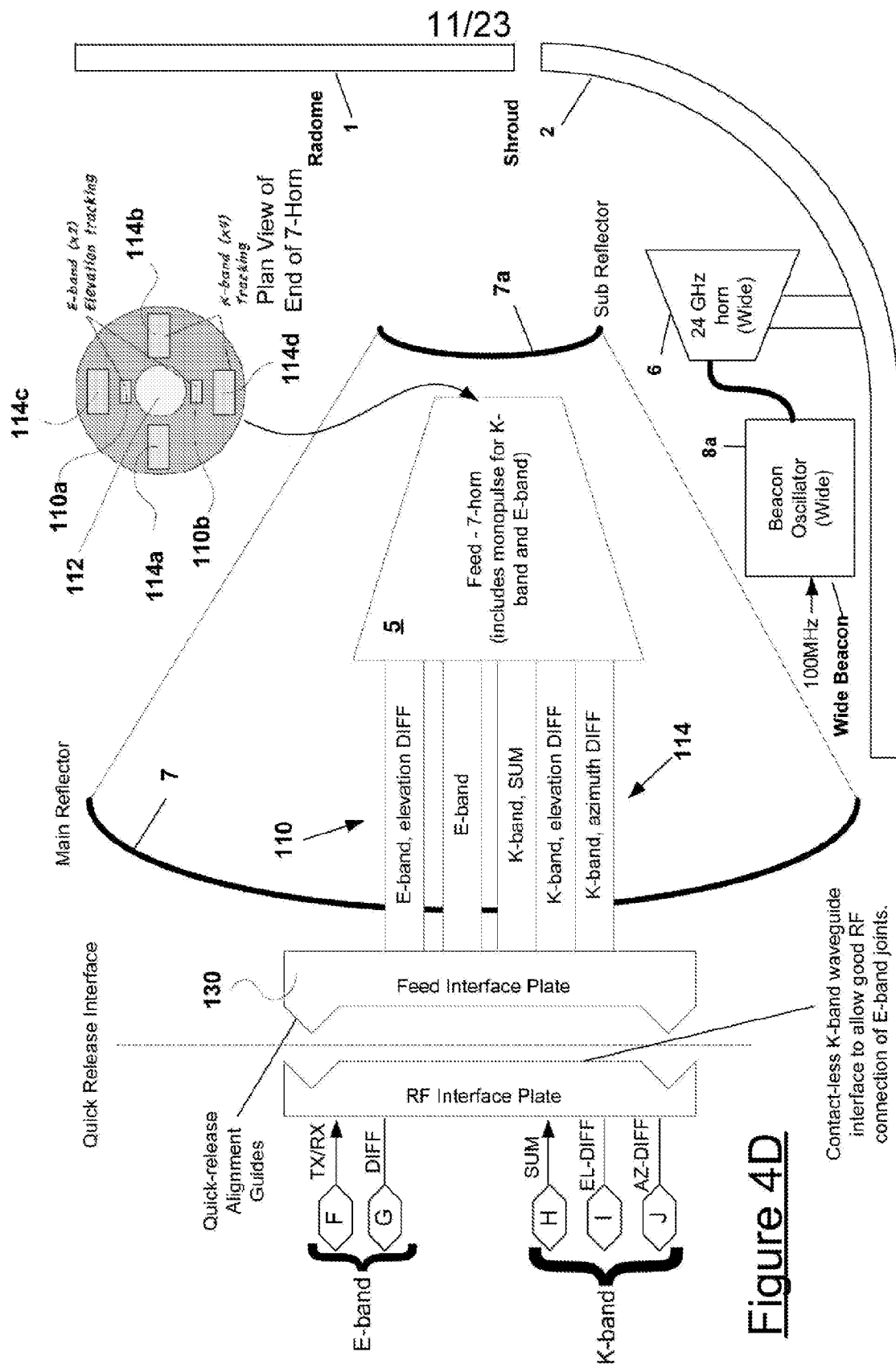


Figure 4D

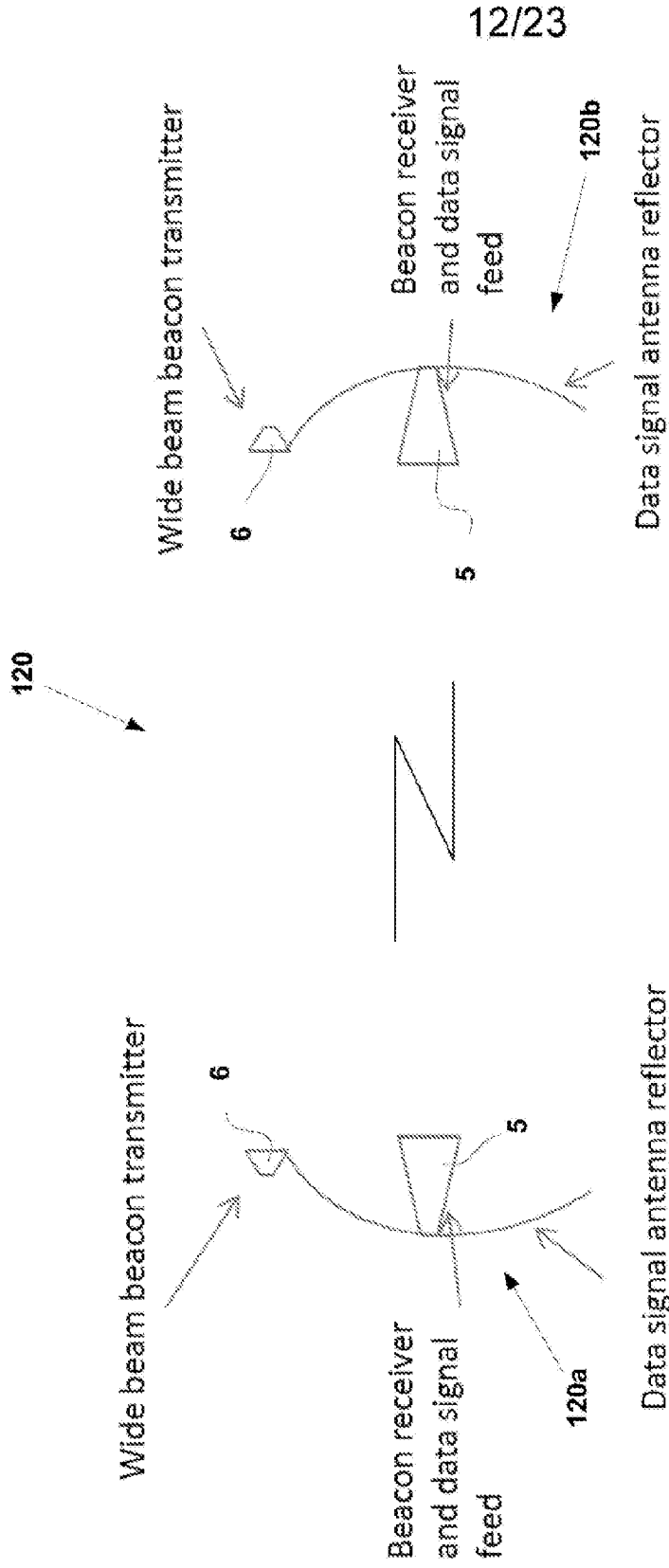


Figure 4E

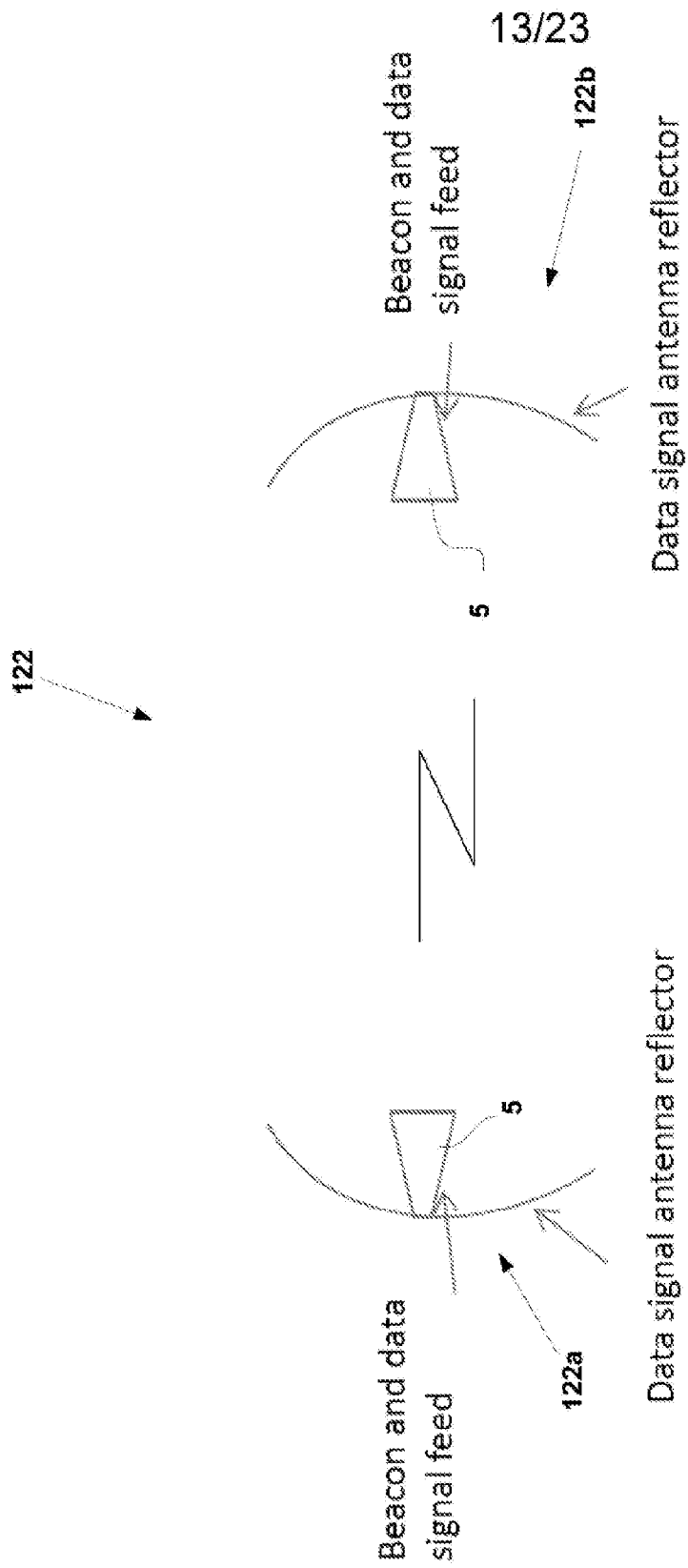


Figure 4F

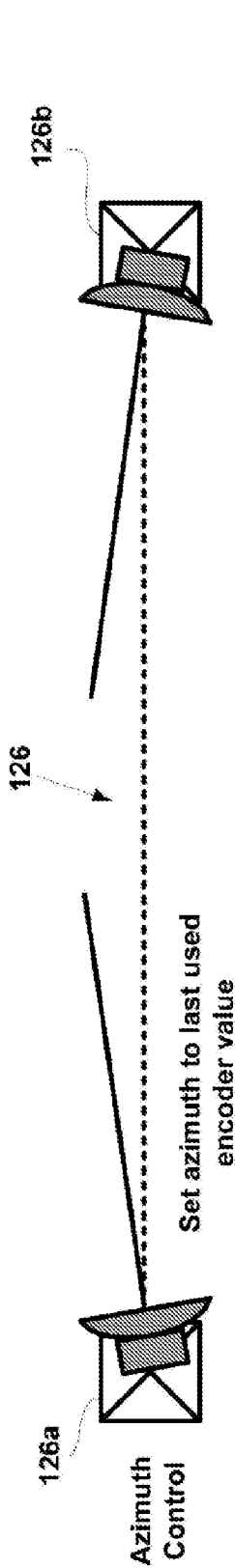


Figure 5A

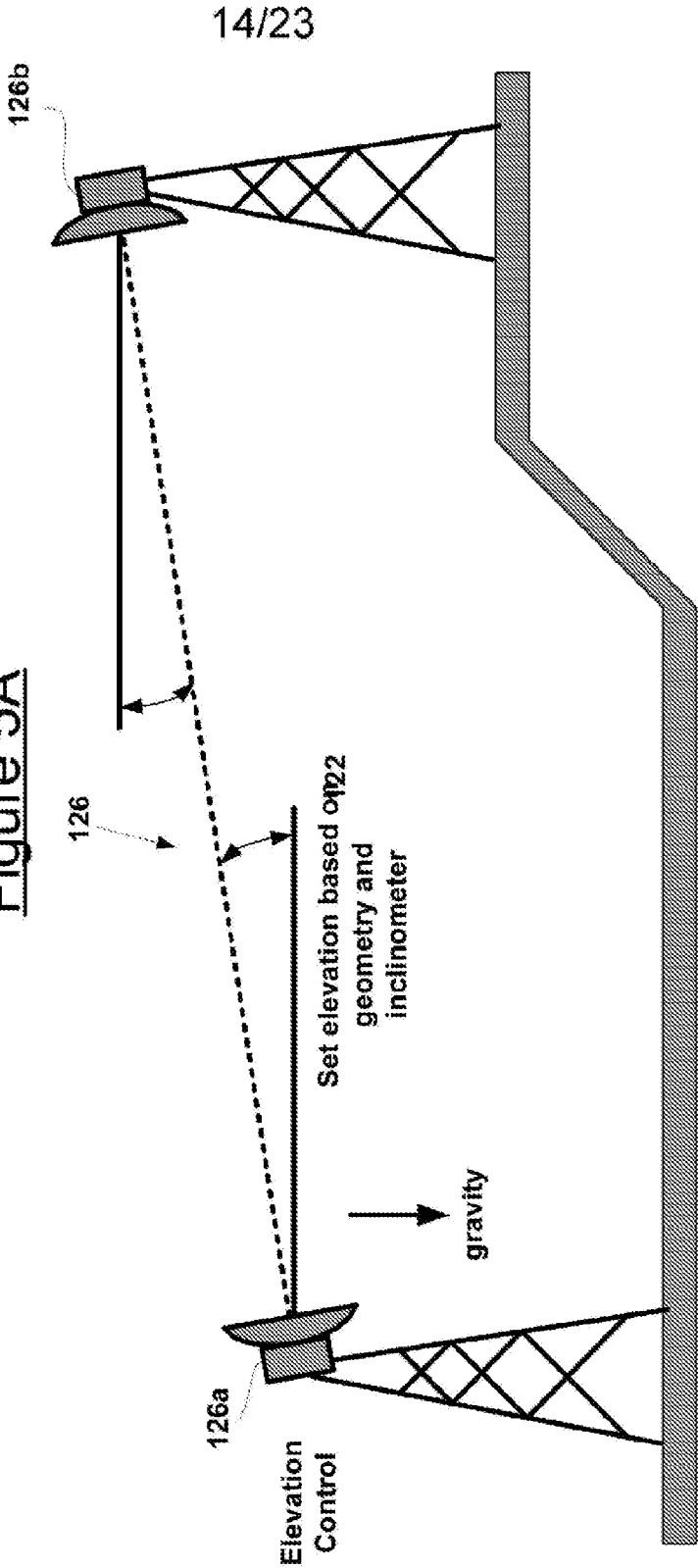


Figure 5B

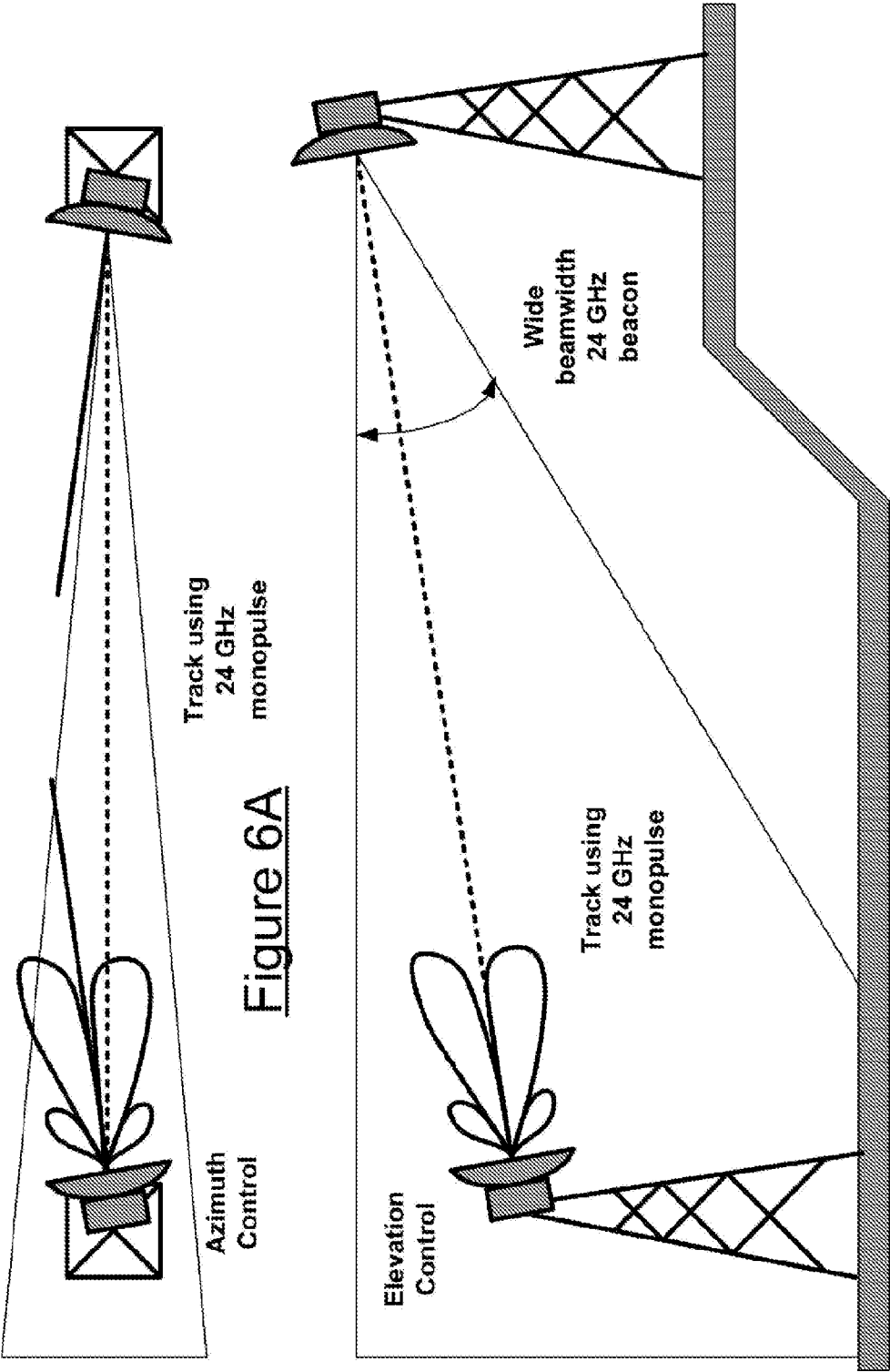


Figure 6A

Figure 6B

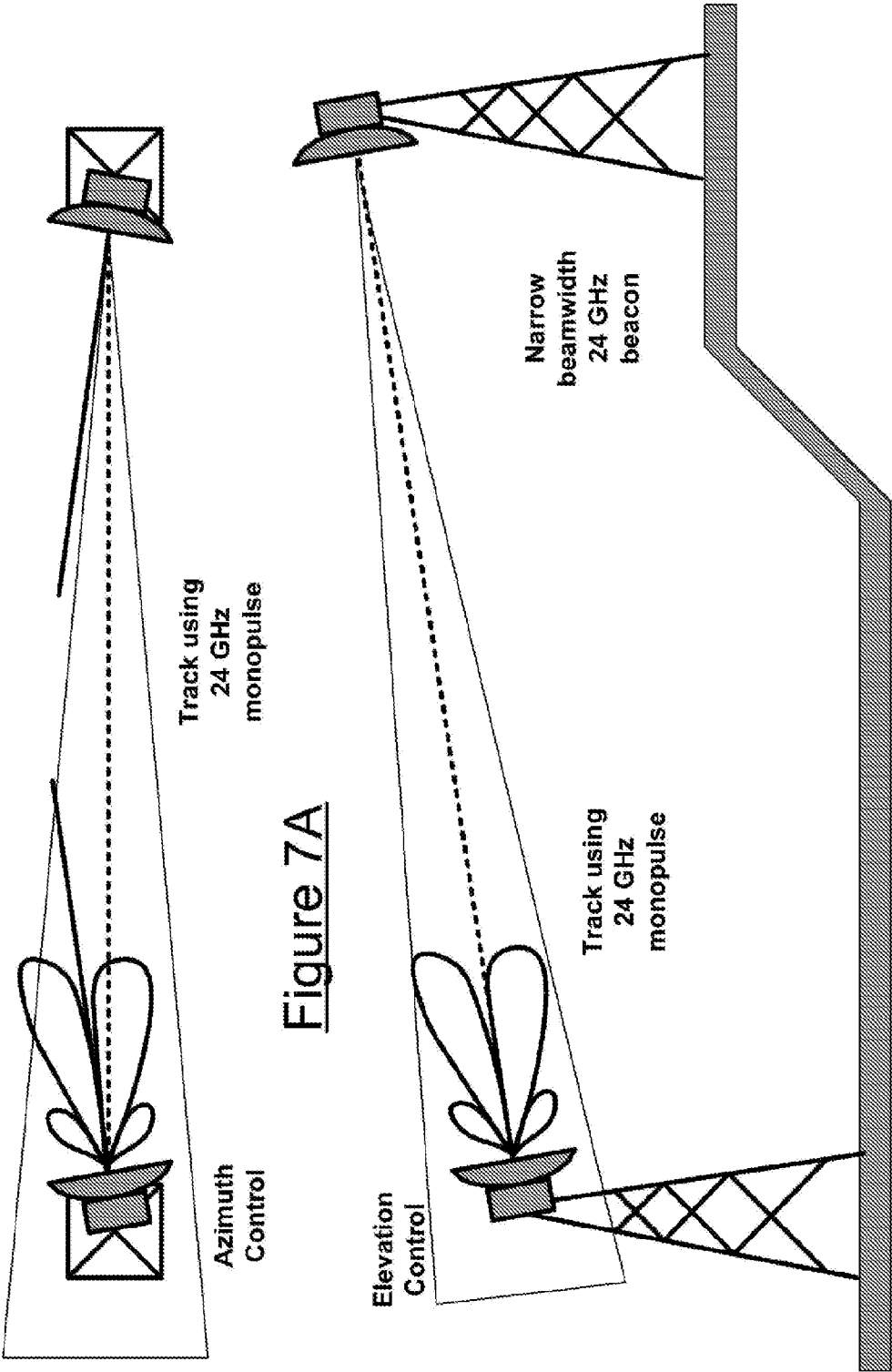


Figure 7B

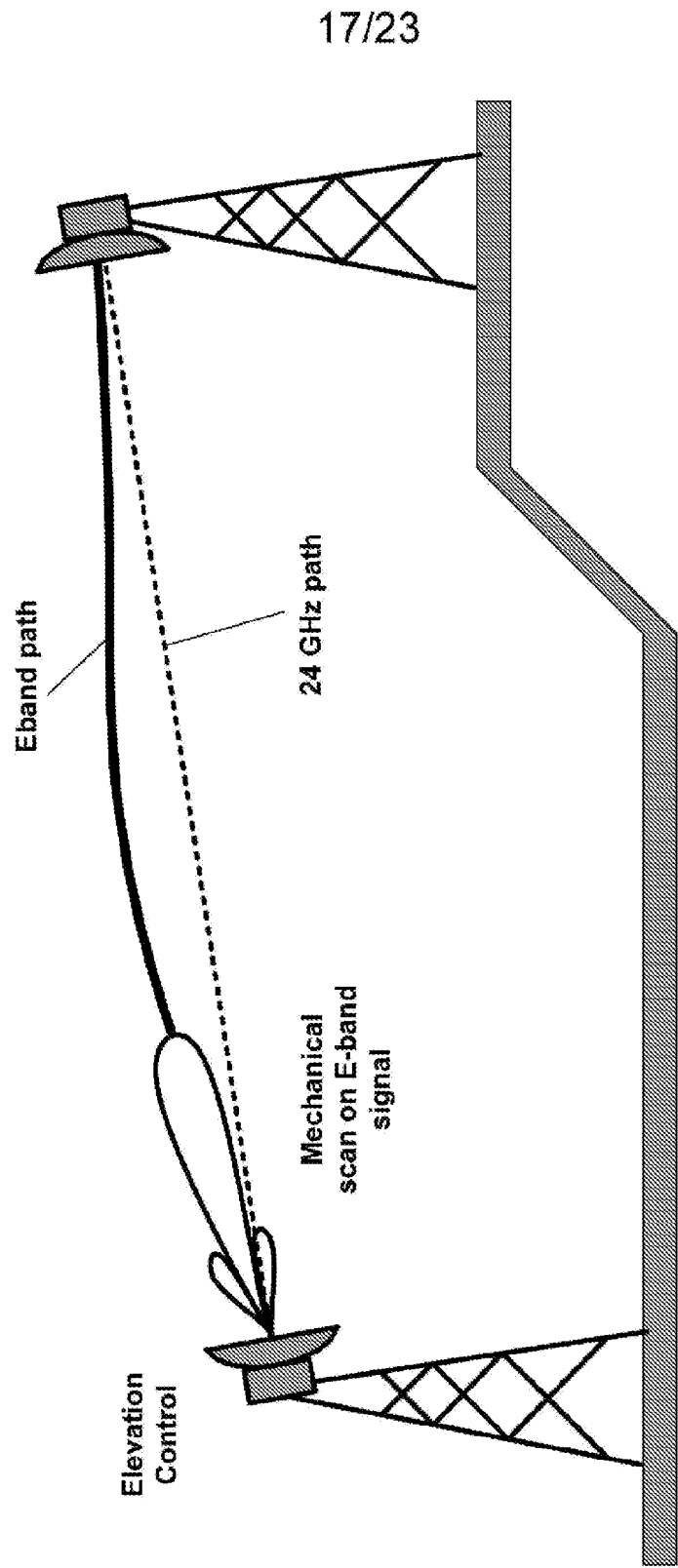


Figure 8

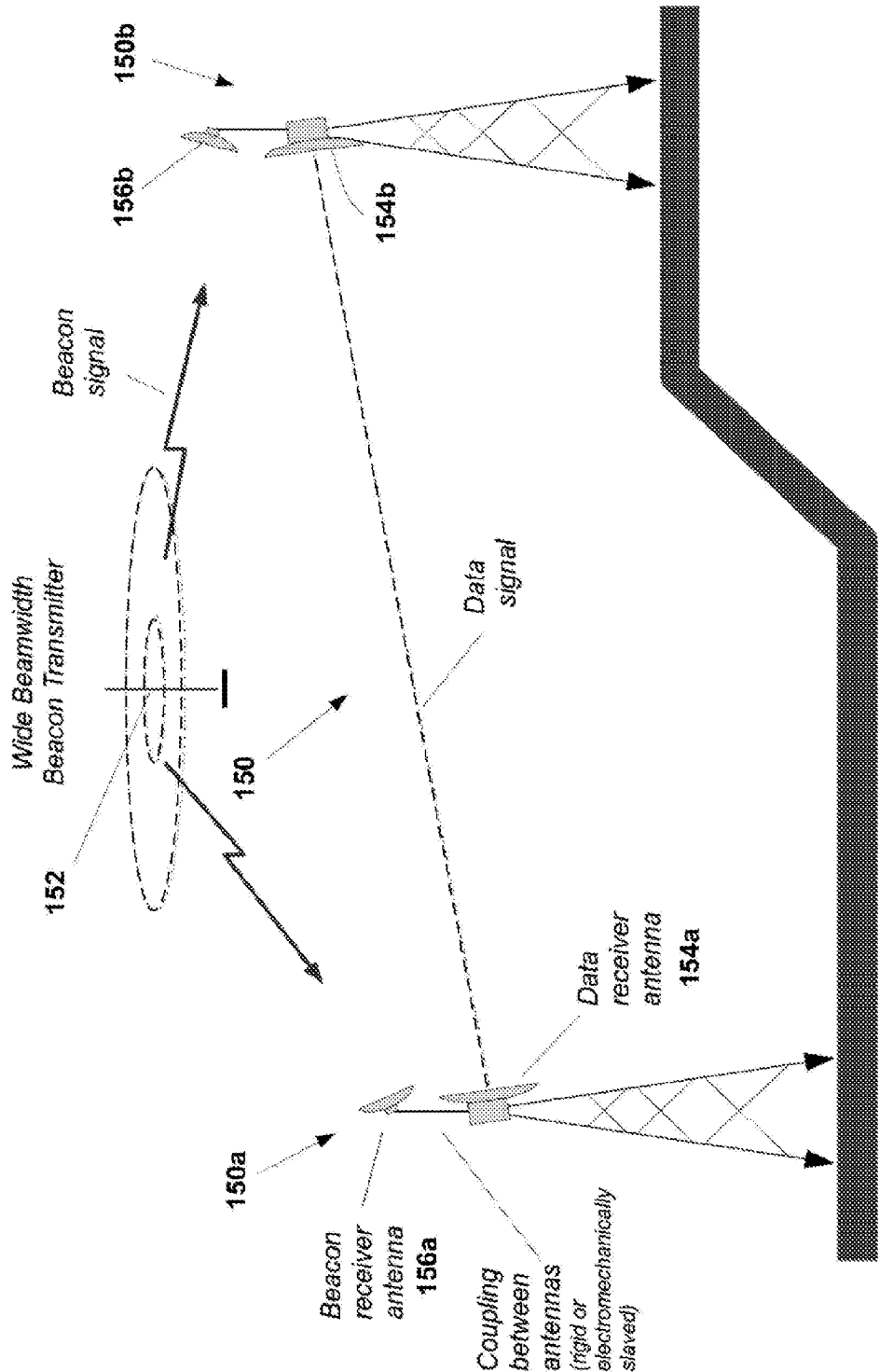


Figure 9

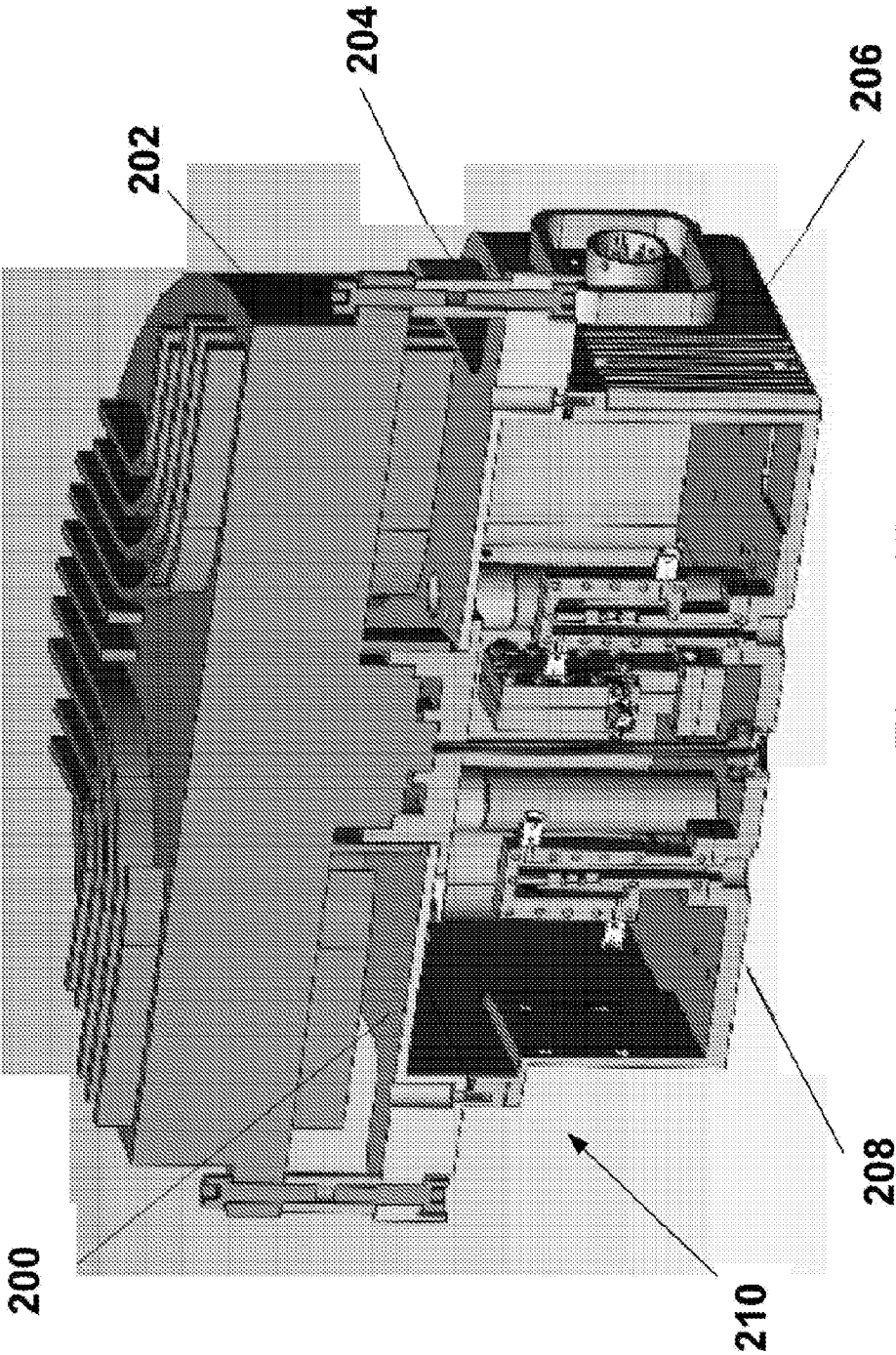


Figure 10

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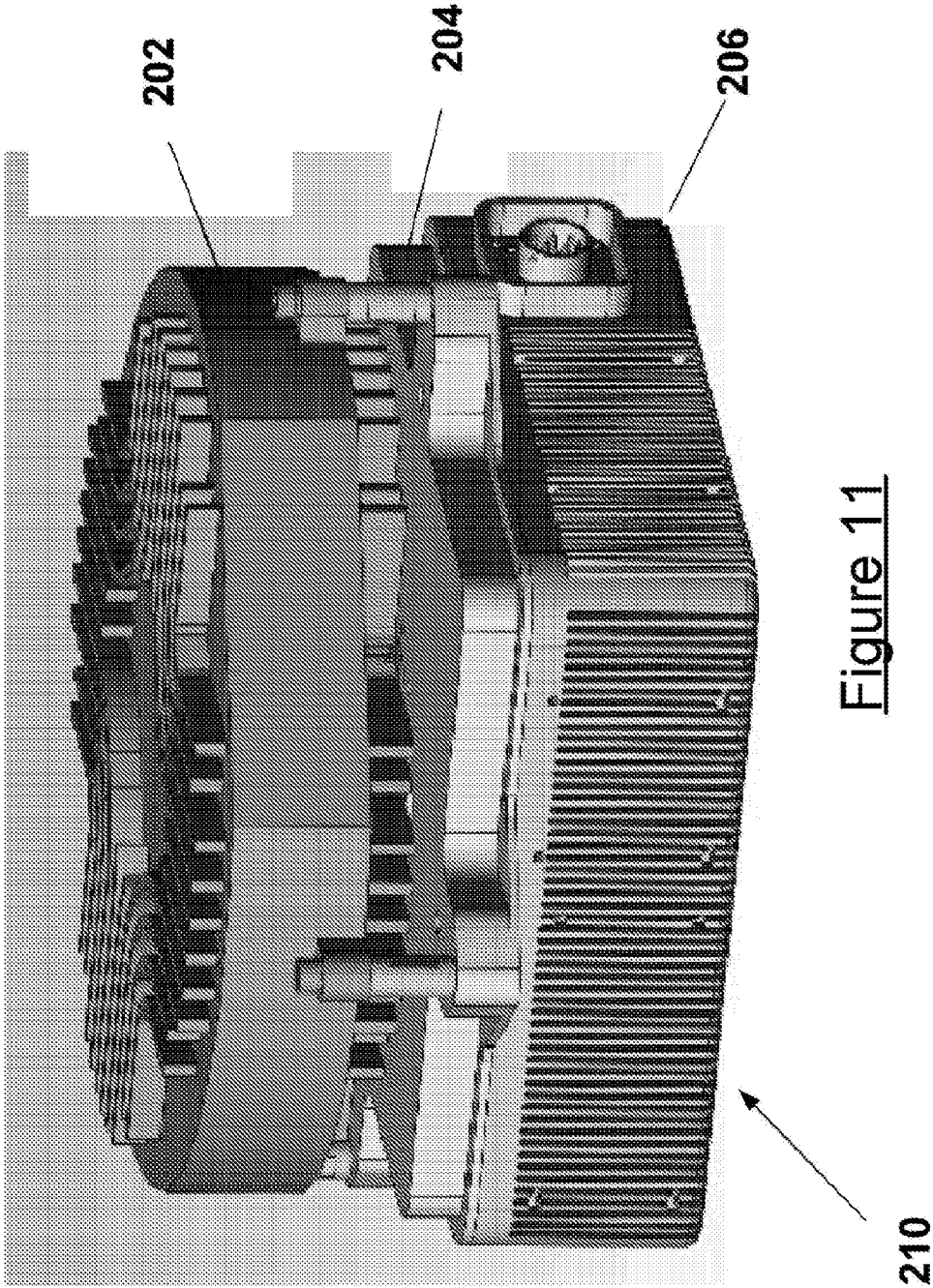


Figure 11

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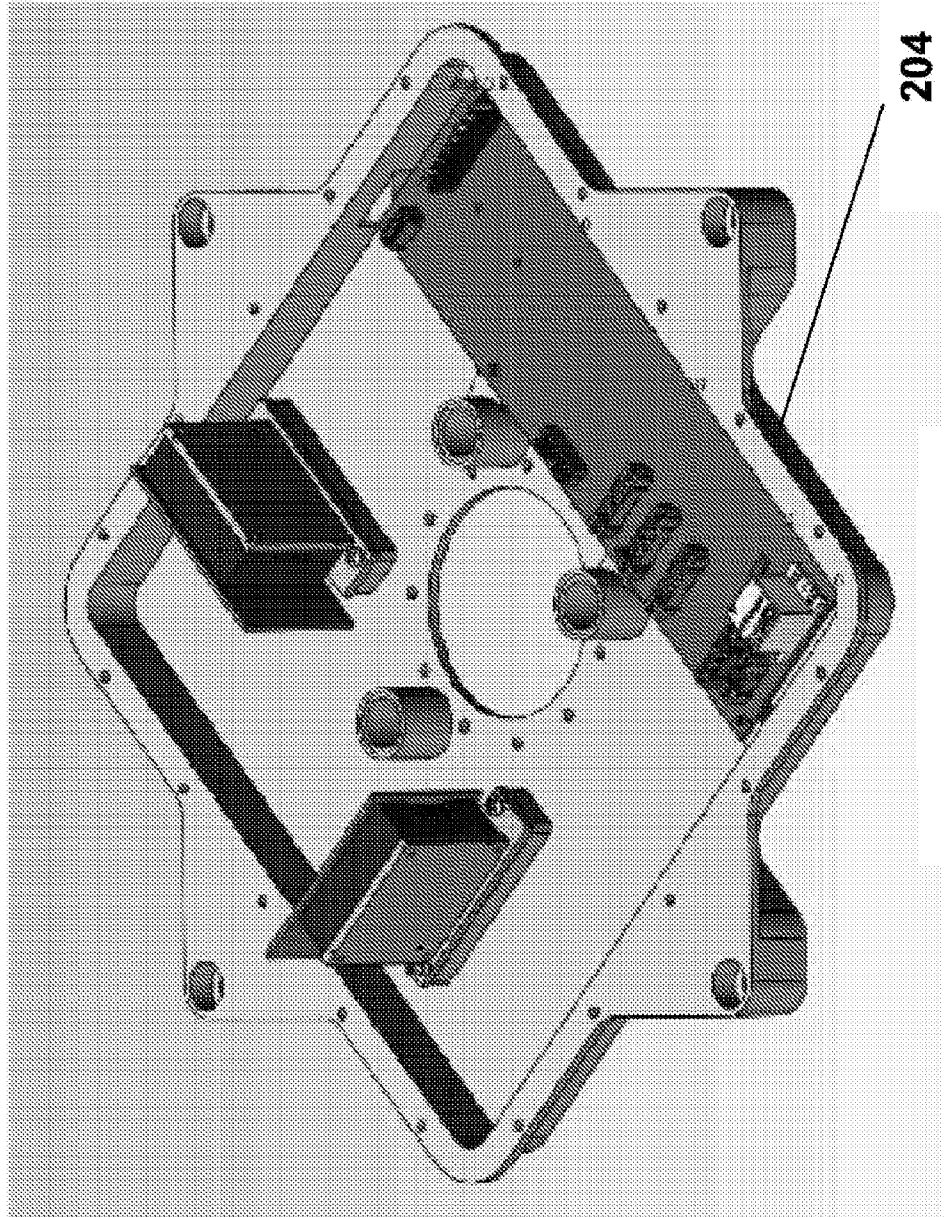


Figure 12

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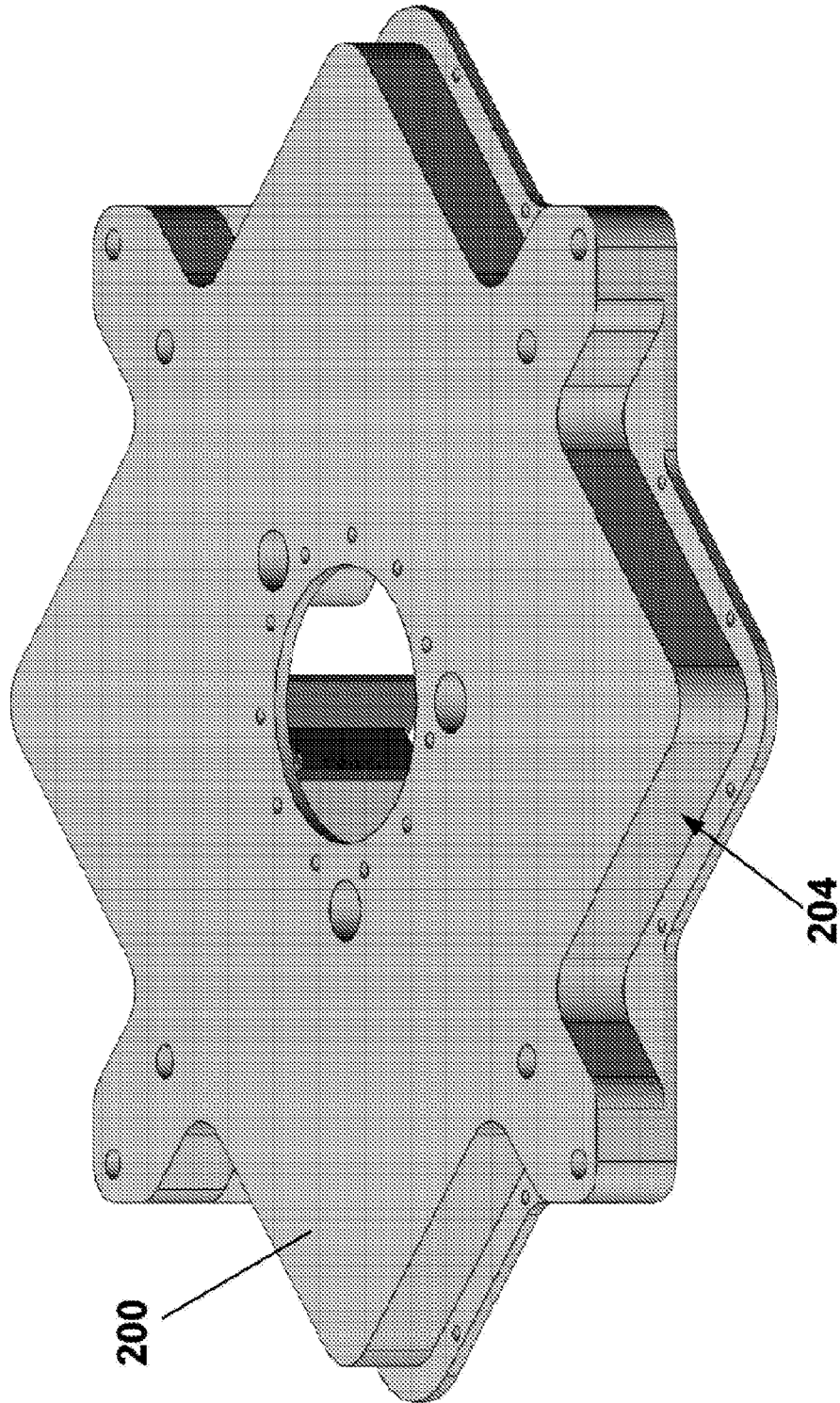


Figure 12A

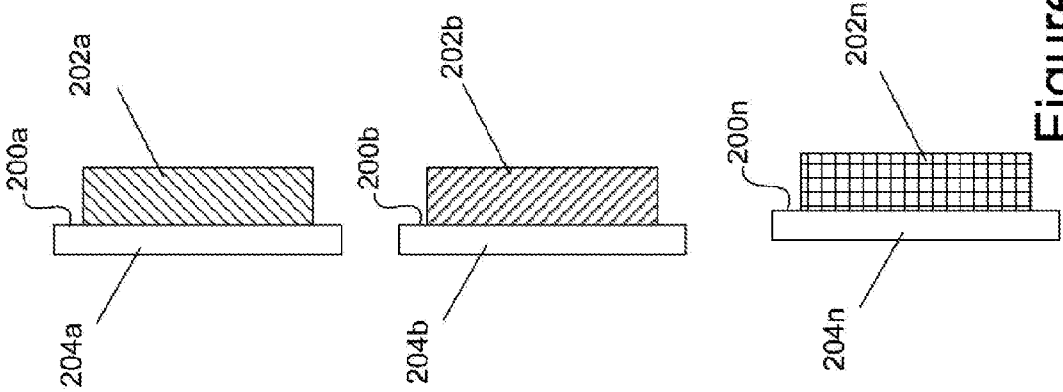


Figure 13B

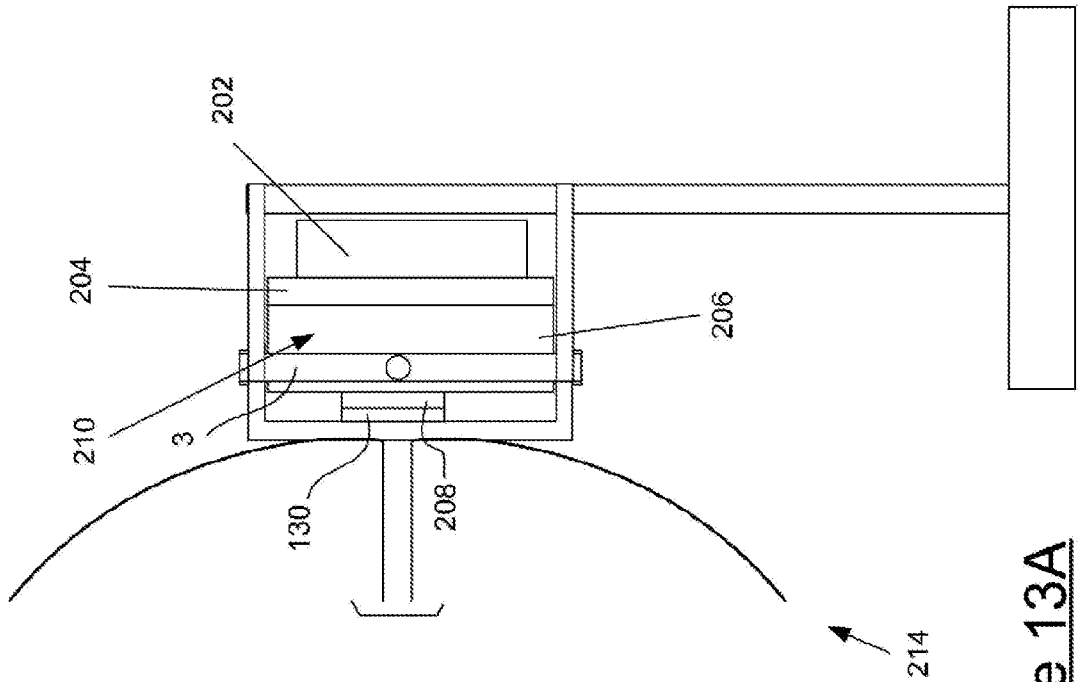


Figure 13A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/000599

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 3/12 (2006.01) G01S 13/00 (2006.01) H01Q 1/20 (2006.01) H01Q 1/12 (2006.01) H01Q 1/42 (2006.01)
H01Q 15/14 (2006.01) H01Q 19/00 (2006.01) H01Q 25/00 (2006.01) H04B 1/38 (2006.01)

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)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, TXTUS5, TXTUS4, TXTUS3, TXTUS2, TXTUS1, TXTUS0, TXTEP1, TXTGB1, TXTWO1, TXTAU1, TXTCA1, TXTSG1, GOOGLE SCHOLAR, THE LENS, FREE PATENTS ONLINE; IPC: H01Q3, H01Q25, G01S13, H04M1 & Keywords: align+, antenna+, beacon?, redirect+, beam, beamwidth, wid+, narrow, first, second, great+, width, direct+, track+, control, scan, monopulse, velocity, position loop, communications link, assembly, radio, stabilize, module, remove, mount+, coupling, interface, base plate; and similar terms; ESP@CE: applie: em solutions; inv: ness, callaghan, harris, rutherford.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



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	"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	
"E" earlier application or patent but published on or after the international filing date	"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	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"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	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
5 September 2014

Date of mailing of the international search report
05 September 2014

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
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Authorised officer

I. G. BIGGS
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No. 0262256118

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2014/000599

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2014/000599
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4837576 A (Schwarz) 06 June 1989 Abstract; Fig. 1-4; col 2 line 24 – col 5 line 15.	1-15, 19-29
X	US 7680516 B2 (Lovberg et al.) 16 March 2010 Abstract; Fig. 3, 9-11; col 6 line 45 - col 18 line 45, col 22 line 25-31.	17
A	US 2010/0201589 A1 (Hellberg) 12 August 2010 Abstract; Fig. 6; paragraph [0059]-[0069].	1-37
A	US 2007/0031151 A1 (Cunningham et al.) 08 February 2007 Abstract; Fig. 1; paragraph [0026]-[0027].	1-37
A	US 2004/0203528 A1 (Ammar et al.) 14 October 2004 Abstract; Fig. 4, 11; paragraph [0040]-[0041], [0098]-[0099].	1-37
A	US 2005/0277402 A1 (Yowakim et al.) 15 December 2005 Abstract; Fig. 1a, 3a; paragraph [0019]-[0023].	1-37

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU2014/000599
Supplemental Box	
Continuation of: Box III This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept. This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups: 1. Claims 1-16, 31, 32 are directed to an apparatus and method. The feature of a link end for a terrestrial communications link including: a directional antenna; a redirecting assembly mounted to the directional antenna; one or more actuators coupled to the redirecting assembly; a control system arranged to control the redirecting assembly in response to variations in the strength of a terrestrial beacon signal is specific to this group of claims. 2. Claim 17, 18 are directed to a terrestrial data communications wireless link. The feature of including: a first link end including a first directional antenna, a first beacon and a first redirecting assembly coupled to the first directional antenna; and a second link end including a second directional antenna, a second beacon and a second redirecting assembly coupled to the second directional antenna; wherein the first directional antenna and the second directional antenna are maintained in mutual alignment by the first redirecting assembly redirecting the first directional antenna in response to a signal from the second beacon and the second redirecting assembly redirecting the second directional antenna in response to a signal from the first beacon is specific to this group of claims. 3. Claims 19 -30 are directed to a method for maintaining a first antenna in a desired direction. The feature of including: redirecting the first antenna in response to variations in a beacon signal received at a location proximate or coincident with the first antenna wherein the beacon signal emanates from a remote beacon is specific to this group of claims. 4. Claims 33-37 are directed to an apparatus, interface assembly and method for mounting any one of a plurality of communications modules to a platform stabilization assembly. The feature of an interface assembly including an interface chassis having a front face arranged to couple to the antenna feed and an interface plate removably fastened to the interface chassis and having a back face arranged to couple to the communications module; wherein the interface plate is one of a number of interface plates each having a back face arranged to complement various coupling configurations of the different communications modules is specific to this group of claims. PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art. When there is no special technical feature common to all the claimed inventions there is no unity of invention. In the above groups 1 to 3 of the claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is redirecting the first antenna in response to variations in a beacon signal received at a location proximate or coincident with the first antenna wherein the beacon signal emanates from a remote beacon. However this feature does not make a contribution over the prior art because it is disclosed in: D1 US 4,837,576 A (Schwarz) 6 June 1989 see Fig. 1-4; col 2 line 24 – col 5 line 15 (Note, the beacon signal emanating from a remote beacon is implicit to D1) Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to the claimed inventions in groups 1-3 and the requirements for unity of invention are consequently not satisfied <i>a posteriori</i>. Furthermore, in the remaining group 4 of the claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to the claims and the requirements for unity of invention are consequently not satisfied <i>a priori</i>.	
Form PCT/ISA/210 (Supplemental Box) (July 2009)	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/000599**Supplemental Box**

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2014/000599	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 4837576 A	06 June 1989	None	
US 7680516 B2	16 March 2010	US 7680516 B2	16 Mar 2010
		AU 2002357339 A1	30 Jun 2003
		AU 2003284133 A1	06 Jun 2004
		CN 1618182 A	18 May 2005
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		CN 101784930 A	21 Jul 2010
		EP 1391058 A1	25 Feb 2004
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Form PCT/ISA/210 (Family Annex)(July 2009)			

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Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2014/000599	
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Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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		WO 2005062943 A2	14 Jul 2005
		WO 2005109059 A2	17 Nov 2005
		WO 2007027827 A2	08 Mar 2007
		WO 2008054350 A2	08 May 2008
		WO 2008118451 A1	02 Oct 2008
		WO 2009097134 A1	06 Aug 2009
		WO 2011115686 A1	22 Sep 2011
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2014/000599	
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Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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		AU 2008244292 A1	06 Nov 2008
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		EP 1986016 A1	29 Oct 2008
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		CA 2618297 A1	02 Feb 2007
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		AU 2003303719 A1	10 Aug 2004
		CN 1735999 A	15 Feb 2006
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		JP 2006513637 A	20 Apr 2006
		KR 20050092400 A	21 Sep 2005
		NO 20053155 A	28 Sep 2005
WO 2004064197 A1	29 Jul 2004		
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End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			