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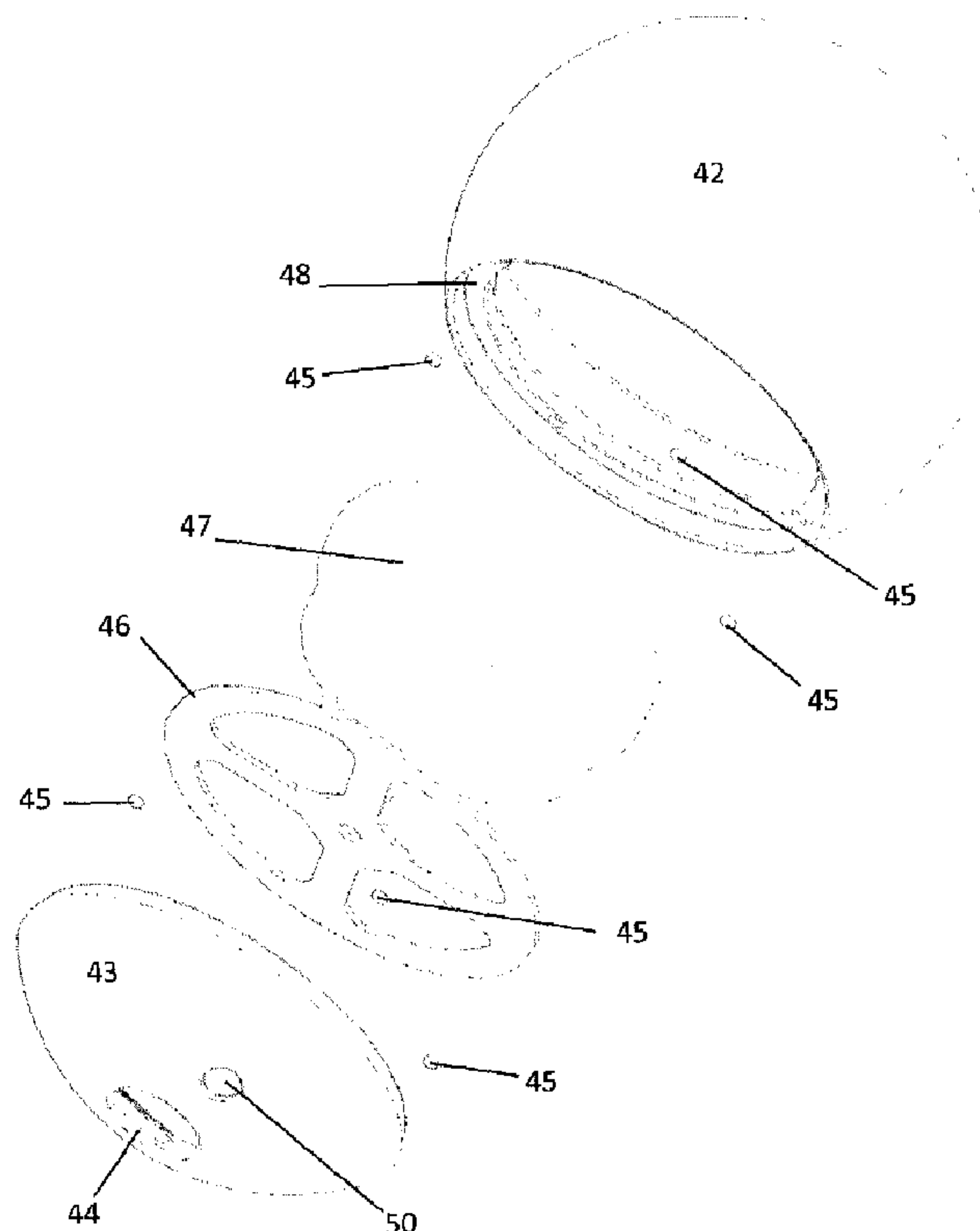
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(54) **Titre : DISPOSITIF DE LEVE AMELIORE ET METHODE DE CAPTURE ET DE GEOREFERENCEMENT DE NUAGE DE POINTS**

(54) **Title: IMPROVED SURVEYING DEVICE AND METHOD FOR CAPTURING AND GEOREFERENCING POINT CLOUDS**



(57) **Abrégé/Abstract:**

A spherical reference target enclosure is provided for use in conjunction with a wireless positioning system, such as a satellite-based positioning system, and a 3D scanner. The spherical reference target is adapted to enclose a GPS receiver such that the



**(57) Abrégé(suite)/Abstract(continued):**

location of the phase center of the GPS receiver's antenna precisely coincides with the center of the spherical reference target. Constructed of a material that both reflects incident laser beams and does not interfere with the GPS performance, the spherical reference target enclosure allows for increased precision and efficiency in registering, within the Earth's coordinate system, data sets collected by the 3D scanner. The spherical reference target enclosure can be used to modify and augment the capabilities of existing surveying systems at low cost. A spherical reference target containing an integral GPS receiver is also provided. A method is provided for operating the spherical reference target and increasing precision and efficiency of a surveying task. A method is provided for conducting surveying using a movable vehicle and a spherical reference target.

**Abstract**

A spherical reference target enclosure is provided for use in conjunction with a wireless positioning system, such as a satellite-based positioning system, and a 3D scanner. The spherical reference target is adapted to enclose a GPS receiver such that the location of the phase center of the GPS receiver's antenna precisely coincides with the center of the spherical reference target. Constructed of a material that both reflects incident laser beams and does not interfere with the GPS performance, the spherical reference target enclosure allows for increased precision and efficiency in registering, within the Earth's coordinate system, data sets collected by the 3D scanner. The spherical reference target enclosure can be used to modify and augment the capabilities of existing surveying systems at low cost. A spherical reference target containing an integral GPS receiver is also provided. A method is provided for operating the spherical reference target and increasing precision and efficiency of a surveying task. A method is provided for conducting surveying using a movable vehicle and a spherical reference target.

## **Improved surveying device and method for capturing and georeferencing point clouds**

### **Field of the invention**

The present invention relates to the field of laser surveying instruments and more particularly to a device and method for referencing with improved precision and efficiency point clouds collected using a laser surveying instrument.

### **Background (*description of the prior art*)**

The science of land surveying aims to determine the terrestrial or three-dimensional position of points and the distances and angles between them. It is essential in the planning and execution of most forms of construction and has occurred ever since humans first began building large structures. The points measured during survey may, for example, be on the surface of the Earth, in a quarry, mine or tunnel, or inside a building.

Modern surveying systems commonly employ a satellite-based positioning system (such as GNSS, GPS, GLONASS, Galileo, IRNSS, BeiDou-2, CPGPS, etc) in combination with a 3-dimensional (3D) scanner or a total station equipped with 3D scanning capabilities, which generally consists of an electronic theodolite integrated with an electronic distance meter (EDM).

3D scanners rely on electro-optical scanning to generate data (for example in the form of point clouds) representing a three-dimensional map of the scanned area. Because the scanned area can be too large for a single scan or because it can contain obstacles blocking the 3D scanner's line of sight to a surface of the desired area, a surveyor is generally required to carry out a plurality of scans and displace the 3D scanner between each scan. This iterative process generates a series of data sets (or point clouds) that must be combined to provide a representation of the complete area. In order to combine these data sets together or to assign absolute coordinates (in other words, within the Earth's coordinate system, as opposed to relative coordinates with respect to the scanner's internal coordinate system) to one or several data sets, a crucial component of modern surveying remains the precise and reliable establishment of the coordinates of at least one selected point within the scanned area.

Establishing the absolute coordinates of at least one selected point is typically, but not exclusively, handled with a satellite-based positioning system. The challenges one faces when measuring the precise position of a ground point relate to the error introduced by the relative position of the measuring device (whether it is a satellite-based positioning system, a prism, or a 2-dimensional

target) with respect to the ground point. Several different approaches for overcoming this challenge have been described in the prior art.

US 5,929,807, to Viney et al., describes a method and apparatus for recording position data of a ground point during survey procedure. Viney et al. propose to use a pole-mounted antenna adapted for use with a satellite-based surveying system. The user is required to place the bottom, or proximal end, of the pole on the ground point and move the pole through a range of orientations while the proximal end of the pole remains in contact with the ground point. Through this action, an antenna, which is placed at the distal end of the pole, travels following the surface of a virtual sphere centered on the ground point and having for radius the length of the pole. By collecting a series of measurements of the antenna's coordinates while the antenna is moved through the surface of the sphere, the location of the center of the sphere and of the desired ground point can be derived through a statistical approximation algorithm, such as least square adjustments. This approach presents major drawbacks: it is labour-intensive and time-consuming as it requires an operator to manually move the pole as measurements are being recorded. The precision this approach aims to achieve may be compromised by any accidental displacement of the distal end of the pole while the pole is being moved and the antenna's location measured. Its precision is further compromised by any variation in the length of the pole. This approach is ill-suited for any automated approach to surveying or 3D scanning as it relies heavily on the actions of an operator and requires the operator to travel from point to point to carry out measurements, which are later manually entered into the scanner or post-processing means.

Another solution is proposed in EP 2,696,167, to Jordil, which describes the use of a still surveying pole equipped with a tilt sensor. An antenna is mounted to the distal end of the pole. The inclination measured by the tilt sensor, in combination with the knowledge of the length of the pole, allows the operator to derive from the coordinates of the antenna the coordinates of the proximal end of the pole, which is placed onto the desired ground point. When used in combination with a surveying system, this system may typically be coupled to a 2-dimensional target. The 2-dimensional target, relative coordinates are measured by the total station and its absolute coordinates are derived from the coordinates of the antenna taking into account the length and inclination of the pole and the coordinates of the antenna.

Inclination sensors can comprise moving parts, which renders them unreliable and sensitive to certain environmental conditions. Strong magnetic fields, for example, can significantly affect their accuracy. Additionally, inclination sensors can be expensive and their use may require alterations to conventional surveying equipment. Finally the accuracy of coordinates obtained through the method described above depends on the skills of their operator.

US 2014/0300886, to Zogg et al., discloses a geodetic surveying system and method for deriving surface information for an object and the relative position of at least one reference point. The system and method disclosed by Zogg et al. also allow to derive the reference point's coordinates with respect to an external coordinate system. The system comprises a 3D scanner that generates a point cloud by scanning the object or area to be surveyed. Based first solely on this scan, the position, orientation and scaling of the cloud is only known with respect to the internal coordinate system of the surveying device. Zogg et al. teach that an absolute position and/or orientation of the point cloud can then be obtained by referencing the point cloud with respect to an overarching, external, coordinate system. This referencing, referred to as registration, can be performed by measuring the precise location with respect to the internal coordinate system of one or a series of individual reference points, whose position with respect to the external coordinate system is known.

To that effect the device disclosed by Zogg et al. comprises, in addition to the scanning functionality, an individual point measuring functionality. Using that functionality, Zogg et al. propose to sight three reference targets. Zogg et al. suggest that retroreflectors may be used as reference targets.

Where the surveying operation requires the collection of multiple point clouds, several scans must be performed either by displacing the 3D scanner or by using a plurality of 3D scanners. In both instances, the orientation of the reference targets must typically be modified for the targets to be facing the total station and produce a better measurement.

Following the method taught by Zogg et al., different point clouds can be linked relative to one another and combined to form an overall point cloud. This method, in combination with the use of a satellite-based positioning system for determining the location of the 3D scanner and/or the location of the reference targets, allows to establish an absolute position of the point cloud in the Earth's coordinate system.

The person skilled in the art will recognize several shortcomings in the device and method disclosed by Zogg et al. Firstly, the step of individually sighting each reference target is time-consuming and the accuracy of the measurement obtained may depend on the skills of the operator. Secondly, the use of 2-dimensional targets requires their displacement for each scan as they must be facing the 3D scanner while they are being sighted. This step further increases the inefficiency of the process as it requires an operator to travel to the reference targets for each scan. This step may also lower the accuracy of the measurement as the rotation of the target may cause an accidental displacement of the target reference. Thirdly, and more importantly, the geographical location of the 2-dimensional targets is obtained by a method known in the art either using a GPS with a pole and pole tilt sensor, or by measuring the location of a point and placing the 2-dimensional target over that point. These methods

are labour intensive and create significant room for error. They may rely on expensive and unreliable equipment (such as tilt sensors) and are generally sensitive to the inclination of the terrain and to any deviation of the pole or tripod from the vertical axis. For these reasons, the method and system disclosed by Zogg et al. may lead to inefficient and imprecise results.

Non-patent literature discloses another approach for facilitating the registration of a plurality of point clouds within a common coordinate system. The person skilled in the art will be familiar with the use of spherical reference targets. These spheres are sized adequately to be easily detected on a surveyed site with a diameter typically in the range of 2 to 7 inches. Their outside surface is adapted to reflect an incident laser. The advantage offered by spherical reference targets is that they do not require to be displaced or re-oriented between each scan as they offer viewers with the same profile independently of the viewer's angle. A plurality of spherical reference targets are typically used together. They are placed in different locations across the target area in such a way that at least 2, and preferably 3, targets are within the line of sight of the 3D scanner during each scan. Several scans of the area are conducted and the spherical reference targets provide common reference points in each scan, thereby allowing the point clouds generated by each scan to be combined. Post processing software, such as Cyclone ®, is used to combine the plurality of point clouds. Small errors introduced during the measurement may be corrected during that stage by relying on additional constraints detected within the various point clouds.

The primary challenge associated with the use of spherical reference targets is the precise determination of their location to register the collected data sets within the Earth's coordinate system. A known approach for determining the spherical reference target's location consists in setting up the reference sphere over a ground point whose location has already been determined, typically using a satellite-based positioning system. A major drawback of this approach is that the relative position of the reference sphere with respect to the ground point may introduce error due to variations in tripod height or terrain inclination. This error is further compounded to the error potentially associated with the earlier determination of the coordinates of the ground point, which was likely derived from coordinates calculated by a satellite-based positioning system whose phase center did not exactly coincide with the ground point. Other known methods employ prisms and retroreflectors and involve additional manipulations, such as substituting the retroreflector for the reference sphere. These methods suffer from the same drawbacks as the previous one in addition to being time-consuming and to relying on the precision of the operator's manipulations.

### **Summary of the invention**

It is therefore an object of the present invention to provide an improved surveying apparatus and

method for reliably, precisely, and efficiently surveying an object, combining a plurality of point clouds, and determining the absolute position of a point cloud within the Earth's coordinate system. To that effect, the present invention discloses a surveying system comprising a 3D scanner and at least one spherical reference target adapted to precisely collect the location of its center within the Earth's coordinate and communicate that location to the 3D scanner.

It is a further object of the invention to provide a spherical reference target enclosure and a method for adapting a conventional surveying system in order to reliably and efficiently record, combine, and geo-reference data sets. The present invention discloses a spherical reference target enclosure adapted to enclose a satellite-based positioning system receiver such that the phase center of receiver's antenna is precisely located in the center of the spherical reference target enclosure. The enclosure is further adapted to reflect laser beams and not interfere with the satellite-based positioning system signals.

It is a further object of the invention to provide a method for using a spherical reference target in combination with a satellite-based positioning system and a 3D scanner, wherein the target and scanner are mounted on a movable platform or vehicle.

These and other objects of the invention will become more apparent to those skilled upon review of the description in view of the drawings.

#### **Short description of the drawings**

Figure 1 shows a representation of a surveying system according to the prior art.

Figure 2 shows a representation of a surveying system according to the prior art.

Figure 3 shows a representation of a surveying system according to the invention.

Figure 4 shows a side perspective view of a target enclosure according to the invention.

Figure 5A shows a bottom perspective view of a target enclosure according to the invention.

Figure 5B shows a bottom perspective view of a target enclosure according to the invention.

Figure 6 show a lateral exploded view of a target enclosure according to the invention.

Figure 7A shows a perspective cross-section view of a target enclosure according to the invention.

Figure 7B shows a lateral cross-section view of a target enclosure according to the invention.

Figure 8 shows a lateral view of a surveying system according to the invention mounted onto a vehicle as per a preferred embodiment of the invention.

Figure 9 shows a front view of a surveying system according to the invention mounted onto a vehicle as per a preferred embodiment of the invention.

Figure 10 shows a flowchart representing the method of acquiring and registering data sets according to a preferred embodiment of the invention.

Figure 11 shows a surveying system according to the invention comprising a plurality of spherical reference targets.

### **Description of the preferred embodiments**

Figure 1 shows a surveying system according to the prior art. The background shows an urban site to be surveyed. 3D scanner 1 is securely mounted onto a tripod placed on a first location on the site. A 2-dimensional (2D) target 2 is securely mounted onto a tripod at a second location on the same site within the line of sight of scanner 1. A satellite-based positioning system receiver 3, for illustration purposes a GPS, is attached to the top of target 2. As taught by the prior art, scanner 1 scans the area and collects a point cloud comprising information relative to target 2. The location of the center of target 2 is derived from the location measured by GPS 3 and is inputted into scanner 1 to assist in georeferencing the point cloud. As highlighted previously, a major flaw of this system is the lack of precision in deriving the precise location of the center of target 2. A first error could be caused by an imprecise measurement of the relative height of GPS 3 with respect to target 2. A more likely error can also be caused by an inclination of the axis formed by target 2 and GPS 3. Target 2 must also be rotated before a second scan is carried out with the scanner displaced to another location in order to ensure that it faces scanner 1. This additional human step delays the process and may introduce additional errors. This approach is further limited by the fact that GPS 3 may partially obstruct the view of target 2 by scanner 1.

Figure 2 shows another surveying system according to the prior art. This system comprises a 3D scanner 21 mounted on a tripod. A first GPS 22 is mounted on top of scanner 21. One 2D target 23 is mounted on a tripod and placed over a point which location is already known. A second 2D target 24

is mounted on a tripod and placed over a point whose location is initially unknown. A second GPS 25 is placed over target 24. By scanning the area, scanner 21 collects the relative position of target 23 and target 24 with respect to each other and with respect to scanner 21. That information combined with the prior known location of target 23 and the locations measured by GPS 22 and GPS 25 allows the surveying system to georeference the measured point cloud with respect to the Earth's coordinate system. This system suffers from some of the same flaws as the one described in figure 1: any inclination of a GPS with respect to the device it sits on will introduce errors. Any margin of error in placing target 23 over a point whose location is known may also introduce errors. The manual rotation of 2D targets 23 and 24 between scans will cause delays and introduce further potential for error.

Figure 3 shows one preferred embodiment of the present invention comprising a 3D scanner 31 mounted on a tripod, a GPS 32 mounted on scanner 31 (GPS 32 may also be contained within the body of scanner 31) and a spherical reference target 33. Target 33 contains a satellite-based location system 34, which for the purposes of illustration will be referred to as GPS 34 but could be any other satellite-based positioning system such as, for example, GNSS, GLONASS, Galileo, IRNSS, BeiDou-2, CPGPS. Spherical target 33 encloses a GPS 34 in a secure manner with the center of the outside spherical surface of target 33 precisely coinciding with the phase center of GPS 34's antenna such that the coordinates measured by GPS 34 coincide with the center of spherical target 33. Target 33 is constructed with a material that does not interfere with the signal of GPS 34. Target 33 is further constructed or coated with a material that will reflect incident laser beams. Target 33 may also be painted, for example in white, to better achieve that objective. A wide range of suitable materials can be used for these two purposes and include, for example: thermoplastic such as ABS, ASA, PVC.

Scanner 31 carries out a scan of the area, thereby collecting point cloud data regarding the relative position of target 33 with respect to scanner 31 and to the area to be surveyed. Within that relative coordinate system, scanner 31 or an external digital processing means (not shown) is adapted to derive the coordinates of the center of spherical target 33. Any numerical analysis method, for example least squares approximation, can be used to this end. The location measured by GPS 34 is then imported into scanner 31 or into the external digital processing means and associated with the center of target 33. Similarly, the location of scanner 31 is automatically derived by scanner 31 or the external digital processing means from the location measured by GPS 32. The point cloud is then automatically georeferenced with respect to the Earth's coordinate system based on the properly assigned coordinates of these two points and the detection by the scanner of the up and down directions over the vertical axis.

Figure 4 illustrates another preferred embodiment of the invention wherein a spherical reference target enclosure 41 is provided. Target enclosure 41 is comprised of an upper section 42 and a lower section

43. It is important to note that both sections are shown as approximately halves of spherical target 41 but they may be dimensioned in various ways, provided that they form a 3D enclosure with an outside spherical shape when combined together. The height of lower section 43 can for example range from 10 to 90% of the diameter of target 41. The height of upper section 42 can similarly range between 90% and 10% of the diameter of target 41. Target enclosure 41 is constructed or coated with a material that reflects incident laser beams but does not interfere with GPS signal. Enclosure 41 can be constructed in a variety of ways such as molding, machining, or 3D printing.

Figure 5A shows a perspective view from below of the same target enclosure 41 composed of an upper section 42 and lower section 43. A circular opening 44 is provided on lower section 43 to allow for the secure placement of target enclosure 41 onto a tripod or pole.

Figure 5B shows a perspective view from below of the same target enclosure 41 further comprising a second circular opening 50 to accommodate a satellite-based positioning system receiver's second antenna.

Figure 6 shows an exploded view of target enclosure 41 according to one preferred embodiment, wherein upper section 42 and lower section 43 are adapted to be coupled to each other in a female-male configuration, respectively. Upper section 42 further comprises an inward-protruding lip 48. A plurality of small magnets 45 are attached to lip 48. A plurality of small magnets 45 is also attached to inward-protruding lip 49 (shown on figure 7) provided on lower section 43. A plate 46, constructed of a ferromagnetic material, is provided and adapted to fit between upper section 42 and lower section 43 such that both sections are securely coupled together through the effect of magnets 45 when target enclosure 41 is closed. Plate 46 is further adapted to ensure that GPS 47 is secured within enclosure 41 such that the phase center of GPS 47's antenna coincides with the center of spherical enclosure 41. To that effect, plate 46 comprises a center hole allowing for GPS 47's lower threaded rod to engage with the tripod or pole, or vice versa, through plate 46. Various spacers (not shown) may be used with the same enclosure 41 to adapt it for use with distinct GPS receivers with different dimensions by creating a gap between the bottom of GPS 47 and the upper surface of plate 46 to always ensure that the GPS receiver's phase center coincides with the center of spherical enclosure 41. Other spacers may also be used to adapt plate 46 to fit different thread sizes and pole coupling mechanisms.

The superimposition of the phase center of the enclosed GPS receiver and the spherical reference target enclosure's center provides a critical benefit over the prior art as it allows to obtain a precise and accurate measurement of the location of the center of the spherical enclosure that is not influenced by any potential tilt of said spherical enclosure. This feature enables the present invention to provide accurate measurement independently of the terrain inclination or structure supporting the spherical

reference target enclosure.

When compared to the prior art methods consisting in superimposing a GPS receiver over a 2-dimensional target, the present invention further provides the added benefit of eliminating the risk of obstructing the view of the target by the 3-dimensional scanner.

Figure 7A shows a perspective cross-section view of target enclosure 41 wherein upper section 42 is coupled to plate 46, which is itself coupled to lower section 43. Both sections and plate 46 are retained together through the action of magnets 45. Inward-protruding lips 48 and 49, more easily visible on figure 7, hold magnets 45.

Figure 7B shows a lateral cross-section view of the same target enclosure 41. As can better be seen on figure 7B, the proportions of upper and lower sections 42 and 43, and the placement of plate 46 allow for the phase center of GPS receiver 47 to coincide precisely with the center of the sphere formed by the outside surface of spherical reference target enclosure 41.

Magnets 45 are one preferred tool to fasten the first section of the target enclosure to the second section of the target enclosure. Many different fastening means may be used to couple together the different parts of the target enclosure. Examples of other acceptable means for fastening the components of the target enclosure include and are not limited to: threads, latch, velcro, etc.

In another preferred embodiment (not shown), the target enclosure is comprised of left and right sections rather than upper section 42 and lower section 43. Another preferred embodiment provides a spherical reference target enclosure comprised of more than 2 outer components. Instead of comprising an upper and lower section 42 and 43, respectively, or a left and right section, it may be comprised of 3, 4, or more parts to accommodate differently shaped GPS receivers. The plurality of parts, when combined, form an enclosure with a spherical outer surface.

In a further preferred embodiment, the spherical reference target contains a GPS and is adapted not to be taken apart or decoupled for use with a different GPS receiver. Such an embodiment may be sealed for use in harsh environments where dust prevention and weather resistance are important considerations.

In a further preferred embodiment, the spherical reference target and encapsulated GPS receiver are adapted to wirelessly transmit the GPS receiver's location to the scanner or any other processing means. Wireless transmission means may, for example, include Bluetooth®, Wi-Fi, or WiMAX.

Reference spheres and reference spheres adapted to be taken apart for compact storing and transportation are known in the art. One example of stackable reference spheres is sold by Laser Scanning America ® and can be found on their website at <http://www.laserscanning-america.com/traveler-sphere-set/>

The present invention departs from the prior art in that spherical target enclosure 41 is built to enclose a GPS receiver and adapted to precisely hold the GPS receiver such that its antenna's phase center coincides with the center of spherical reference target 41. Such a system provides increased precision and efficiency and allows its operator to automatically register a point cloud within the Earth's coordinate system without conducting additional reading, such as sighting a target, or displacing any component on the surveyed site, such as replacing a reference sphere with a retroreflector or GPS receiver. The present invention derives precise results independently of the inclination of the terrain or the tilt of the pole or tripod supporting the reference target as the phase center of the GPS receiver's antenna remains at the center of the spherical reference target enclosure independently of its tilt thereby eliminating the requirement that the target be levelled. The invention further eliminates the need that the operator manipulate the reference target after it is placed on the site and eliminates the possibility of introducing error through that manipulation.

The advantages of the present invention will become even clearer in view of figure 10, which shows a flowchart of the method for acquiring and registering point clouds according to one preferred embodiment of the invention as shown in Figure 11. In step 101, an operator sets up a 3D scanner 111 on the site to be surveyed. In step 102, the operator sets up a plurality of spherical reference targets (112, 113, 114) on the site to be surveyed and within the direct line of sight of the scanner. Each of the plurality of spherical targets (112, 113, 114) is assigned an identifier (ID). In step 103, the operator conducts a scan of the area with scanner 111 thereby generating a data set, which contains information relative each spherical target (112, 113, 114), as per step 104. From that information is derived the position of the center of each of the plurality of spherical targets (112, 113, 114) with respect to the scanner. In parallel with steps 103 and 104, the GPS receiver contained within each of the plurality of spherical targets (112, 113, 114) calculates its geographical location, which coincides with that of the center of the respective spherical target. In step 105, each spherical target's geographical location (as determined by the respective GPS) and ID are either automatically transmitted or manually entered into scanner 111 or into an external digital processing means (not shown). Target ID and geographical location are assigned to each target's relative location derived from the scan. Once the relative location of the center of each spherical target (112, 113, 114) is matched with its geographical location as measured by the respective GPS receivers contained in each spherical target, the dataset is registered within the Earth's coordinate system.

In another preferred embodiment, one scanner equipped with a first GPS and at least one spherical reference target containing at least a second GPS are provided. A series of scans are conducted with the scanner being displaced between each scan. The first GPS is used to derive the location of the scanner during each scan. The at least one spherical reference target is placed on the site and not displaced. The geographical locations of the scanner and of the center of the spherical reference target that are obtained by their respective GPS receivers are imported into the scanner or into an external digital processing means and associated with the dataset generated by each scan. The location of two points (scanner and center of the spherical target) and vectors derived from those two points in each dataset allow to automatically combine the different datasets into a single dataset and register that dataset within the Earth's coordinate system.

Figures 8 and 9 show one preferred embodiment of the invention used on a platform or vehicle. A vehicle 81 is shown in the form of a truck but could take the form of any movable platform or vehicle, motorized or nonmotorized. Spherical reference target 82 is provided with the properties previously described with reference to reference target 33 or to spherical reference target enclosure 41 containing a GPS. Spherical reference target 82 is mounted on a first end of vehicle 81. Reference target 82 encloses a GPS receiver such that the location of the phase center of the receiver's antenna coincides with the center of spherical reference target 82. A scanner 83 is mounted at the second end of vehicle 81 preferably levelled and at a height that will allow a clear line of sight of target 82 and a clear line of sight of the largest possible portion of the area to be surveyed without impeding the movements of vehicle 81. Scanner 83 may be mounted on a self-levelling mount (not shown). A GPS 84 is mounted on top of scanner 83. The set-up of the invention as shown in figures 8 and 9 allows an operator to precisely and efficiently conduct the surveying of a road or any infrastructure that can be travelled through with vehicle 81. The operator stops vehicle 81 in a first location, conducts a first scan generating a first data set comprising information about the relative location of target 82 with respect to scanner 83. The relative location of the center of target 82 with respect to scanner 83 is derived from the data set relative to spherical target 82. While vehicle 81 is stopped, the GPS contained within target 82 calculates the position of its phase center, which coincides with the center of spherical target 82. For each scan and dataset, the GPS-determined location of scanner 83 and of target 82's center is either automatically or manually uploaded into scanner 83 or into an external digital processing means. Vehicle 81 can then be moved to a new location where it is stopped and a new scan conducted. Successive scans preferably overlap partially in order to provide additional cloud constraints through overlapping points in the surveyed area. These additional cloud constraints can later be used to perform additional error correction. Successive scans generate successive datasets, which can then be registered together and into the Earth's coordinate system based on the geographical location of scanner 83 and target 82 measured by GPS 84 and the GPS contained within spherical reference target 82 during each respective scan.

The system and method as illustrated in figures 8 and 9 differ from the known prior art, such the mobile scanner Pegasus ® manufactured by Leica ®, in many ways. Firstly, it is operated when the vehicle is stopped whereas the Pegasus ® system is adapted for being used with a moving vehicle. Secondly, the invention relies on the use of the spherical reference target disclosed in the present application, which is not found in the Pegasus ® system. Finally, the spherical reference target enclosure disclosed in the present application can be used to adapt any conventional surveying system using a 3D scanner and satellite-based positioning systems into the system illustrated in figures 8 and 9.

In view of the recent developments in the field of surveying devices, devices such as 3D scanners, total stations and multi stations increasingly share overlapping functionalities. For the purposes of this application reference to these devices is made interchangeably and 3D scanners are to be interpreted as encompassing total stations and multi stations.

Similarly, with the satellite-based positioning systems are understood as covering other wireless means of positioning such as indoor positioning systems relying on Wi-Fi access points or magnetic positioning.

**What is claimed:**

1 - A spherical reference target enclosure for use with a wireless positioning system and a 3-dimensional scanner, the spherical reference target enclosure comprising:

- 5           a spherical outer housing, and  
               an inner compartment

wherein

the inner compartment is contained within the spherical outer housing,

the spherical outer housing is adapted to reflect an incident laser beam,

- 10           the inner compartment is adapted to:

receive and hold a wireless positioning system receiver having an antenna and  
 operating within a frequency range, and

hold the receiver such that the phase center of the wireless positioning system  
 receiver's antenna coincides with the center of the spherical outer housing;

- 15           the spherical reference target enclosure is adapted to not interfere with electromagnetic  
 waves within the frequency range operated in by the wireless positioning system receiver.

2 - The spherical reference target enclosure recited in claim 1, wherein the wireless positioning system is a satellite-based positioning system.

3 - The spherical reference target enclosure recited in claim 1 or 2, further comprising:

- 20           a plurality of parts,  
 wherein the plurality of parts form the spherical outer housing when detachably engaged  
 together.

- 4 - The spherical reference target enclosure recited in claim 3, wherein the plurality of parts are  
 individually equipped with fastening means for releasably coupling the plurality of parts  
 25           together.

5 - The spherical reference target enclosure recited in any one of claims 1 to 4, further  
 comprising a plate housed within the inner compartment and adapted to secure the receiver such  
 that the location of the phase center of the wireless positioning system receiver's antenna  
 coincides with the center of the spherical outer housing.

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6 - The spherical reference target enclosure recited in any one of claims 1 to 5, further comprising:

at least one circular opening for allowing the securing of the spherical reference target enclosure onto a support with the use of a threaded rod.

5 7 - The spherical reference target enclosure recited in any one of claims 1 to 6, further comprising wireless transmission means for wirelessly communicating information generated by the wireless positioning system receiver to an external digital processing means.

8 - The spherical reference target enclosure recited in claim 7, wherein the wireless transmission means uses Wi-Fi, Bluetooth®, WiMAX, or any other wireless communication protocol.

10 9 - A spherical reference target for use with a 3-dimensional scanner, comprising:

a spherical outer housing, and

a wireless positioning system receiver comprising an antenna with a phase center and operating within a frequency range,

wherein

15 the wireless positioning system receiver is contained within the spherical outer housing,

the spherical outer housing is adapted to reflect an incident laser beam,

the phase center of the wireless positioning system receiver's antenna coincides with the center of the spherical outer housing; and

20 the spherical reference target is adapted to not interfere with electromagnetic waves within the frequency range operated in by the wireless positioning system receiver.

10 - The spherical reference target of claim 9, wherein the wireless positioning system is a satellite-based positioning system.

25 11 - The spherical reference target recited in claim 9 or 10, further comprising wireless communication means for wirelessly transmitting information generated by the wireless positioning system receiver to a 3-dimensional scanner or to an external digital processing means.

12 - The spherical reference target recited in claim 11, wherein the wireless communication means uses Wi-Fi, Bluetooth®, WiMAX, or any other wireless communication protocol.

13 - A surveying system for collecting and registering within an overarching coordinate system a data set mapping an area to be surveyed, which comprises:

a 3-dimensional scanner,

5 at least one wireless positioning system receiver, each of the at least one wireless positioning system receiver comprising an antenna having a phase center,

at least one spherical reference target having an outer surface, and

digital processing means,

wherein

10 one of the at least one wireless positioning system receiver is enclosed within each of the at least one spherical reference target such that the phase center of the wireless positioning system receiver's antenna coincides with the center of the respective spherical reference target,

the 3-dimensional scanner is adapted to generate a data set representative of the surveyed area within a first coordinate system,

15 the digital processing means is adapted to derive within the first coordinate system the coordinates of the center of at least one spherical reference target from the coordinates, in the first coordinate system, of a plurality of points lying on the outer surface of the at least one spherical reference target,

20 the at least one wireless positioning system receiver is adapted to calculate the coordinates of its phase center within a second coordinate system,

the digital processing means is adapted to match the coordinates in the second coordinate system of each of the at least one wireless positioning system receiver to the coordinates in the first coordinate system of the center of the at least one respective spherical reference target,

25 the digital processing means is adapted to register the generated data set within the second coordinate system based on the matching of the coordinates of the at least one wireless positioning system receiver and center of the at least one spherical reference target.

30 14 - The system recited in claim 13, wherein the wireless positioning system is a satellite-based positioning system.

15 - The system recited in claim 13 or 14, the coordinates calculated by the at least one wireless positioning system receiver are transmitted wirelessly to the digital processing means.

16 - The system recited in claim 15, wherein the wireless transmission uses Wi-Fi, Bluetooth®, WiMAX, or any other wireless communication protocol.

5 17 - The system recited in any one of claims 13 to 17, further comprising a movable vehicle, wherein

the 3-dimensional scanner, the at least one spherical reference target, and the at least one wireless positioning system receiver are mounted onto the movable vehicle.

10 18 - A method for collecting and georeferencing a data set using a 3-dimensional scanner, at least one wireless positioning system, and at least one spherical reference target enclosure, each of the at least one wireless positioning system comprising an antenna with a phase center, the method comprising the steps of:

- 15 a. enclosing one wireless positioning system receiver in each of the at least one spherical reference target enclosure such that the phase center of the wireless positioning system receiver's antenna coincides with the center of the respective spherical reference target enclosure,
- b. placing the at least one spherical reference target enclosure on a site to be surveyed,
- c. placing the 3-dimensional scanner on the site to be surveyed,
- d. conducting a scan of the site using the 3-dimensional scanner,
- 20 e. generating a data set mapping the site within a first coordinate system,
- f. determining within a second coordinate system the position of the phase center of the antenna of each of the at least one wireless positioning system receiver,
- g. determining within the first coordinate system the location of the center of each of the at least one spherical reference target enclosure,
- 25 h. matching the coordinates, within the second coordinate system, of the phase center of the antenna of each of the at least one wireless positioning system receiver to the location of the center of each of the at least one spherical reference target enclosure within the first coordinate system, and
- i. registering the data set within the second coordinate system.

30 19 - The method recited in claim 18, wherein the wireless positioning system is a satellite-based positioning system.

20 - The method recited in claim 18 or 19, wherein the second coordinate system is the Earth's coordinate system.

21 - The method recited in any one of claims 18 to 20, further comprising the step of wirelessly transmitting the coordinates of the phase center of the antenna of each of the at least one wireless positioning system receiver to a digital processing means.

22 - The method recited in any of claims 18 to 21, further comprising the steps of:

- 5       j. repeating steps c) to i) at least one time, and
- k. combining the different data sets acquired through successive scans into a single data set.

23 - A method for collecting and georeferencing a data set using a 3-dimensional scanner, at least one wireless positioning system, and at least one spherical reference target enclosure, each of the at least one wireless positioning system comprising an antenna with a phase center, the  
10   method comprising the steps of:

- a. enclosing one wireless positioning system receiver in each of the at least one spherical reference target enclosure such that the phase center of the wireless positioning system receiver's antenna coincides with the center of the spherical reference target enclosure,
- 15   b. securing the at least one spherical reference target enclosure to a first end of a movable platform,
- c. securing the 3-dimensional scanner to a second end of the movable platform,
- d. placing still the movable platform at a location on the site to be surveyed,
- e. conducting a scan of the site using the 3-dimensional scanner,
- f. generating a data set mapping the site within a first coordinate system,
- 20   g. determining within a second coordinate system the position of the phase center of the antenna of each of the at least one wireless positioning system receiver,
- h. determining within the first coordinate system the location of the center of each of the at least one spherical reference target enclosure,
- i. matching the coordinates, within the second coordinate system, of the phase center of the  
25   antenna of each of the at least one wireless positioning system receiver to the location of the center of each of the at least one respective spherical reference target enclosure within the first coordinate system, and
- j. registering the data set within the second coordinate system.

30   24 - The method of claim 23, wherein the wireless positioning system is a satellite-based positioning system.

25 - The method recited in claim 23 or 24, wherein the second coordinate system is the Earth's coordinate system.

26 - The method recited in any one of claims 23 to 25, wherein the movable platform is a motorized vehicle.

35

27 - The method recited in any one of claims 23 to 26, further comprising the step of wirelessly transmitting the coordinates of the phase center of each of the at least one wireless positioning system receiver to a digital processing means.

28 - The method of any of claims 23 to 25, further comprising the steps of:

- 5       k. repeating steps d) to j) at least one time, and
- l. combining the different data sets acquired through successive scans into a single data set.

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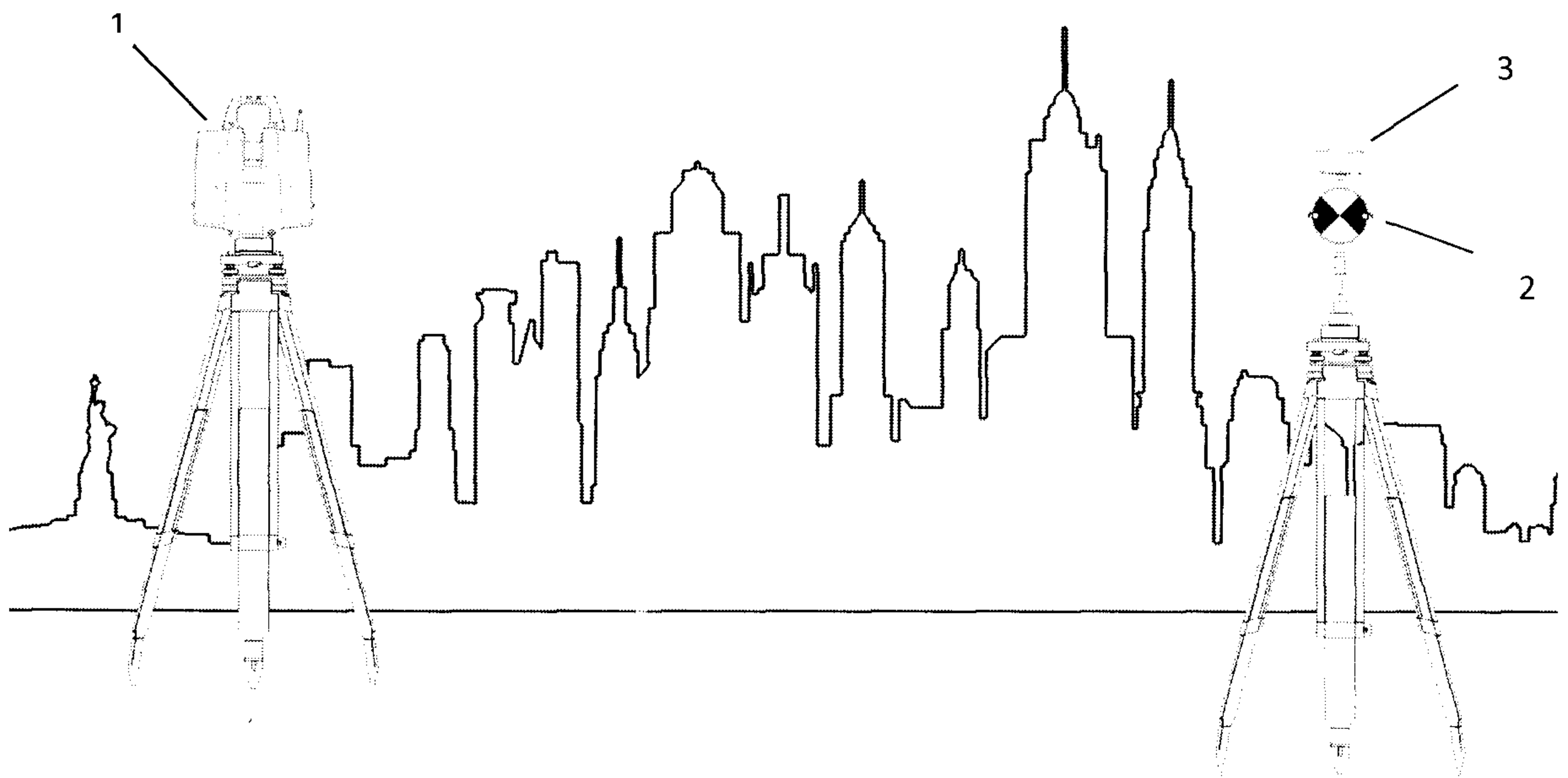


Figure 1  
(Prior art)

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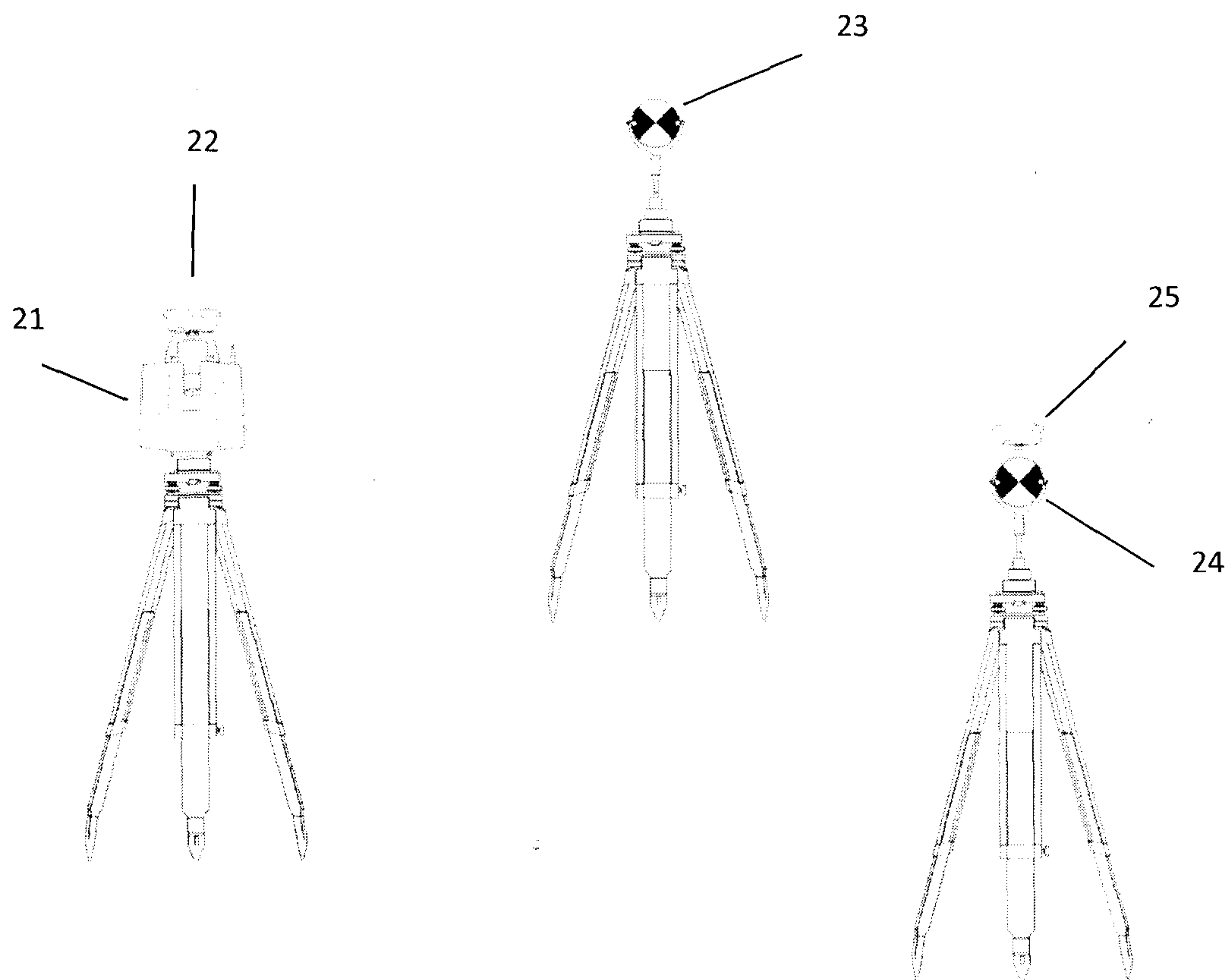


Figure 2  
(Prior art)

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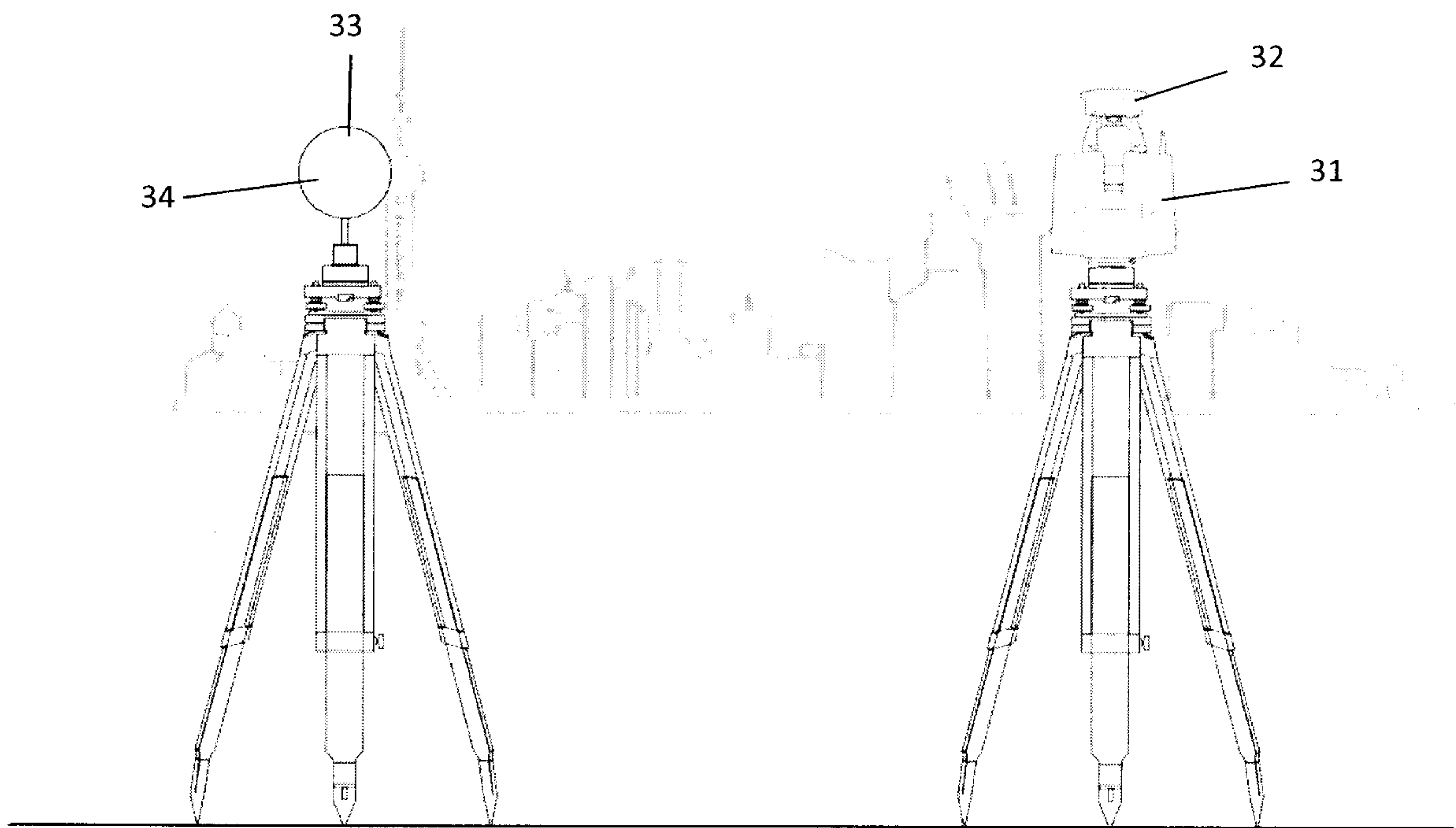


Figure 3

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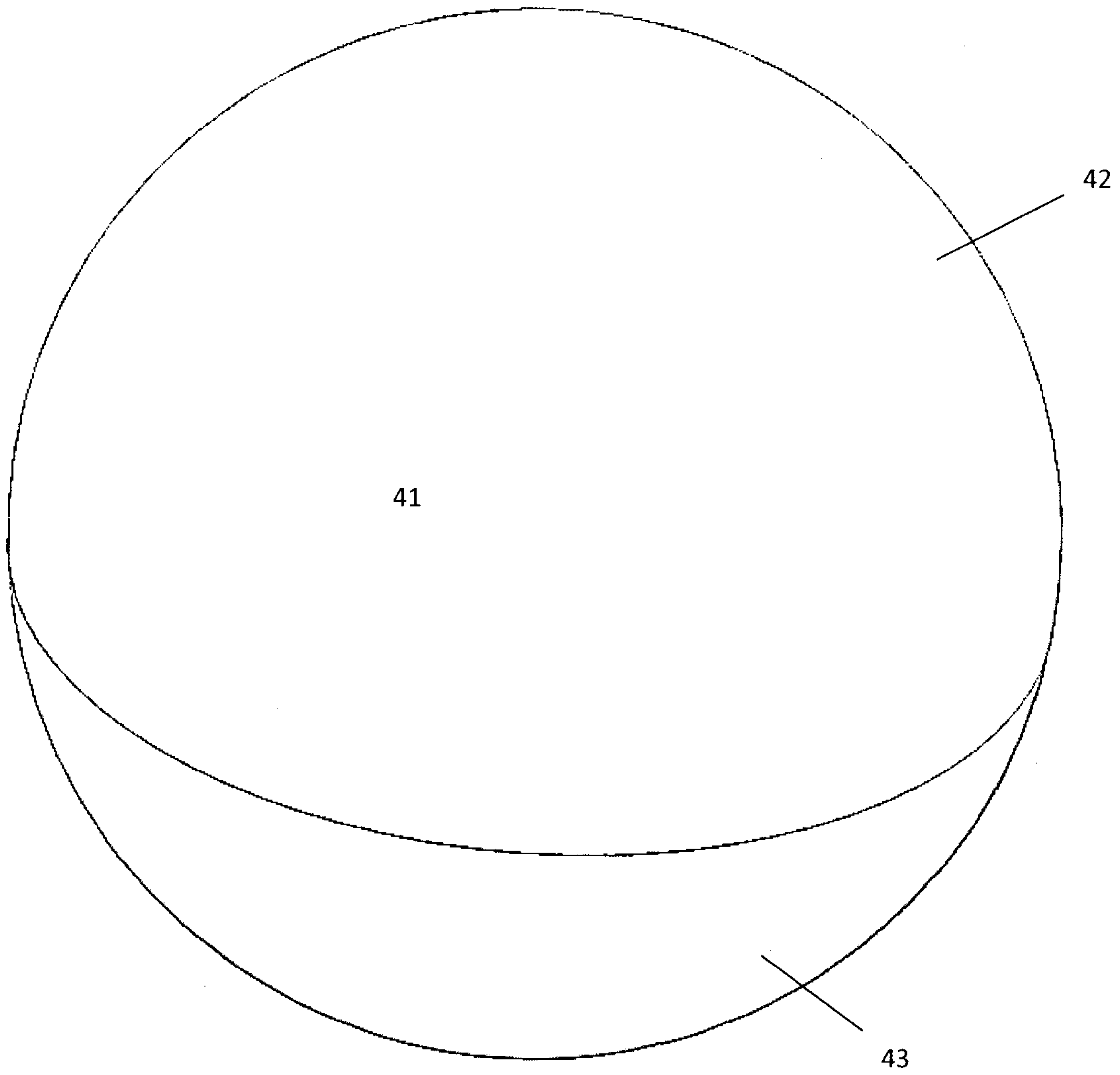


Figure 4

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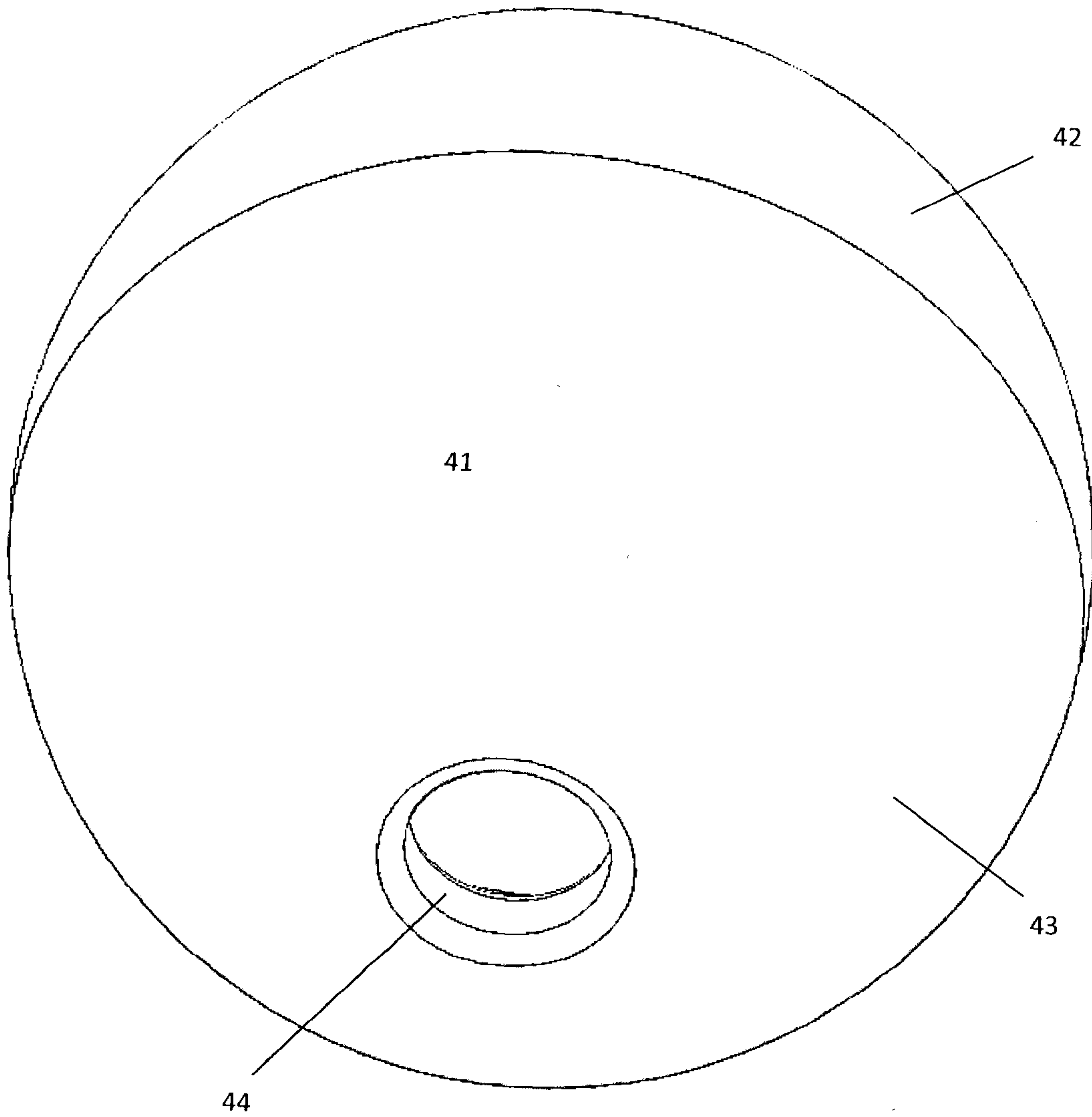


Figure 5A

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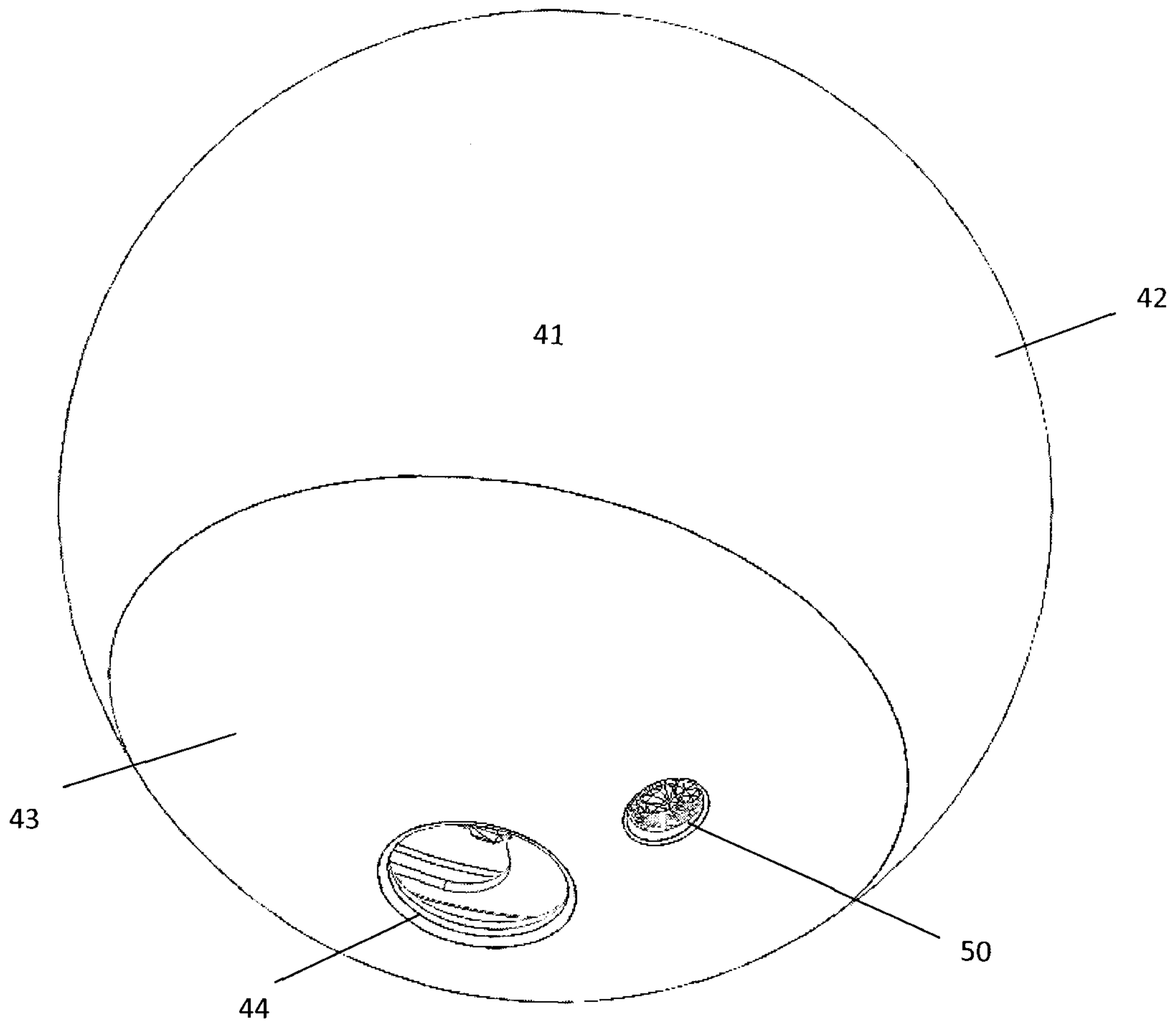


Figure 5B

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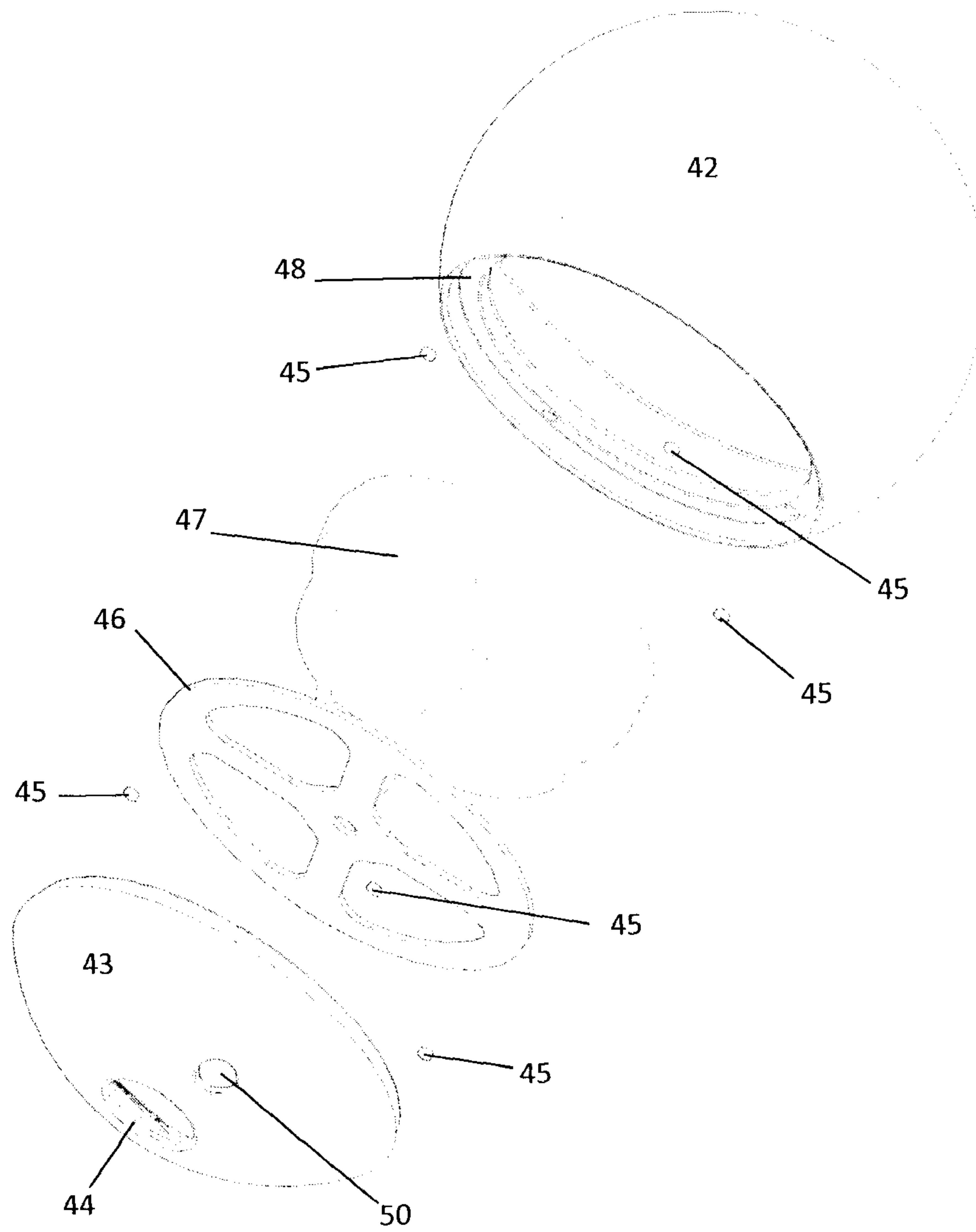


Figure 6

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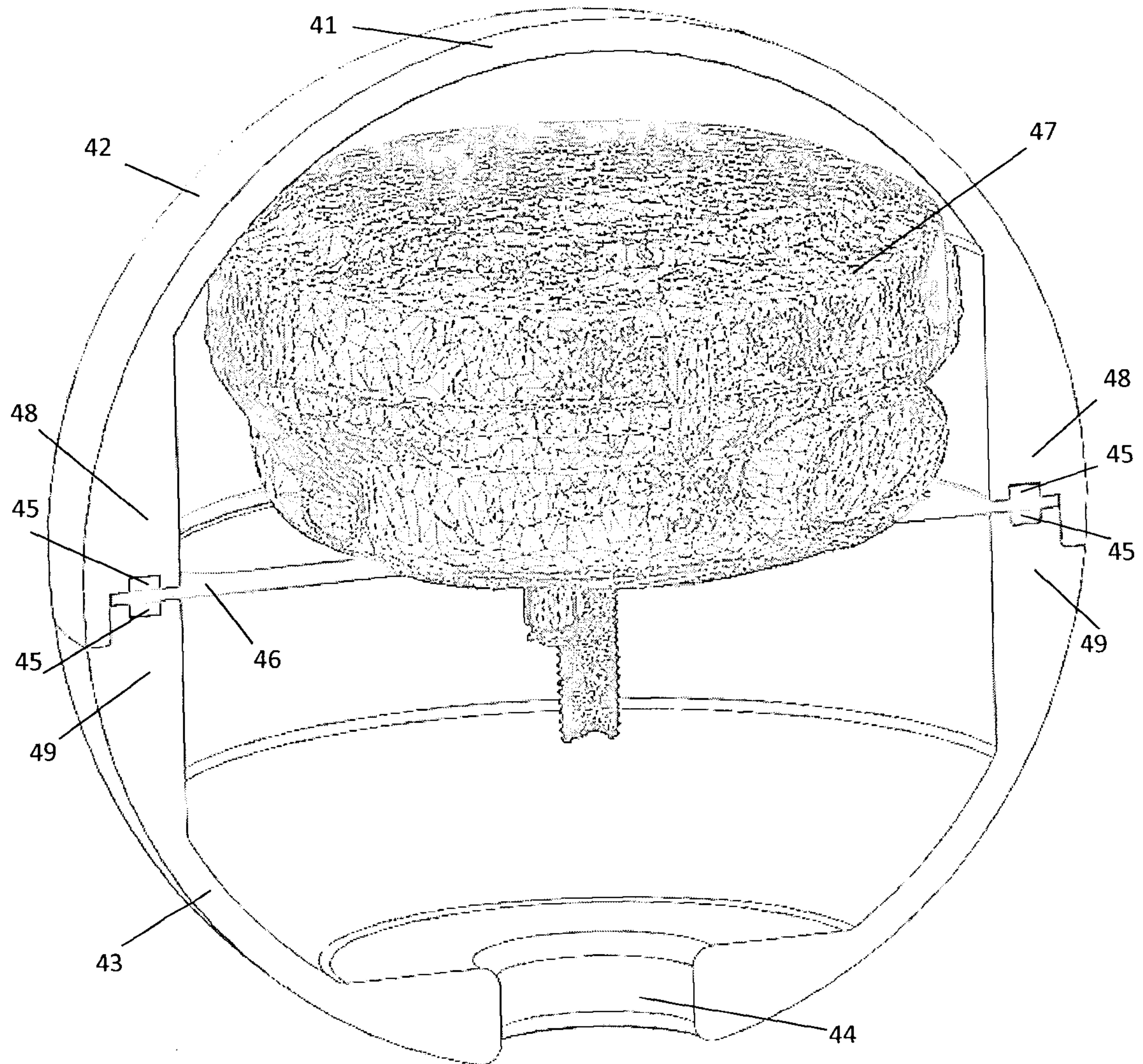


Figure 7A

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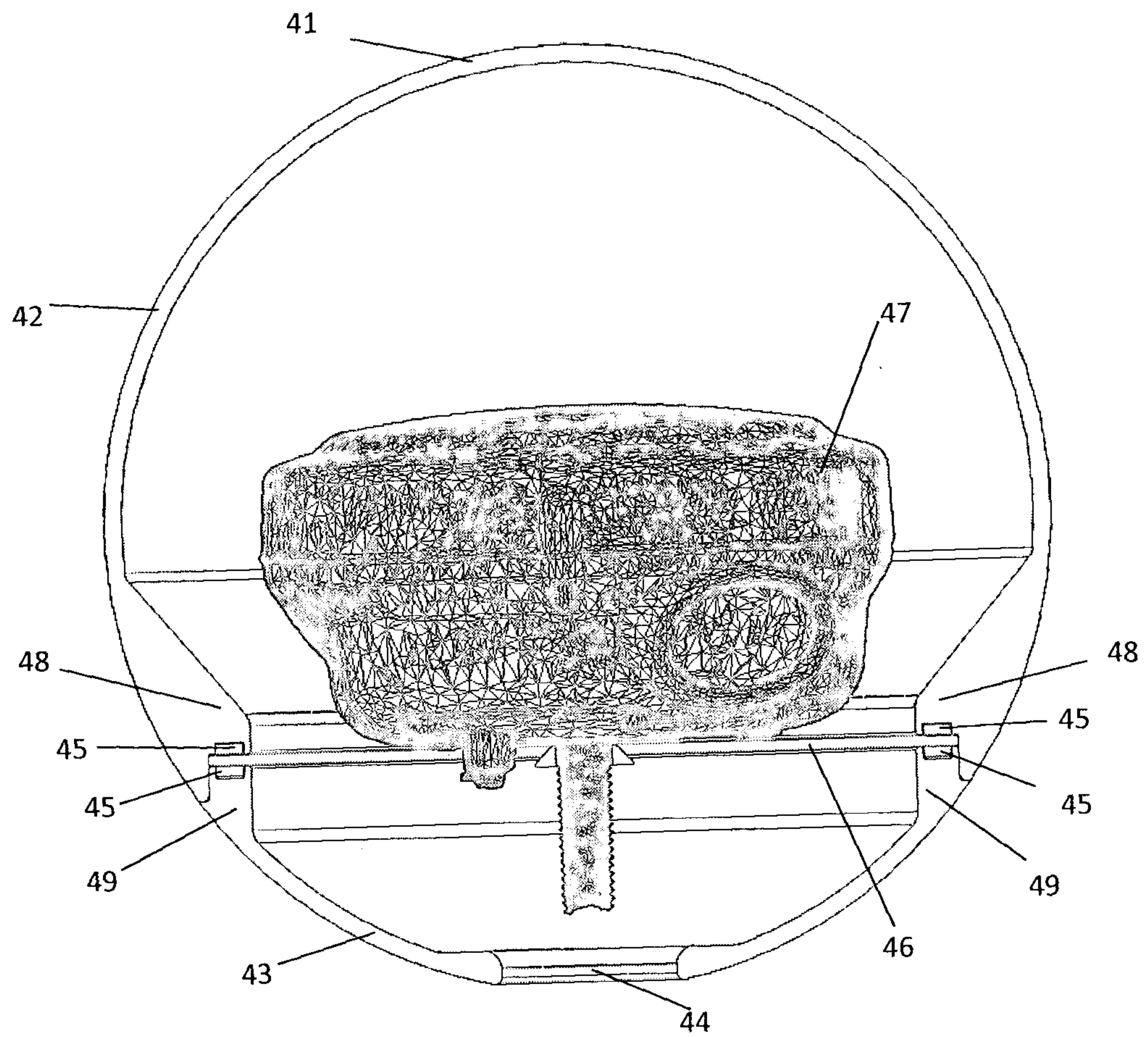


Figure 7B

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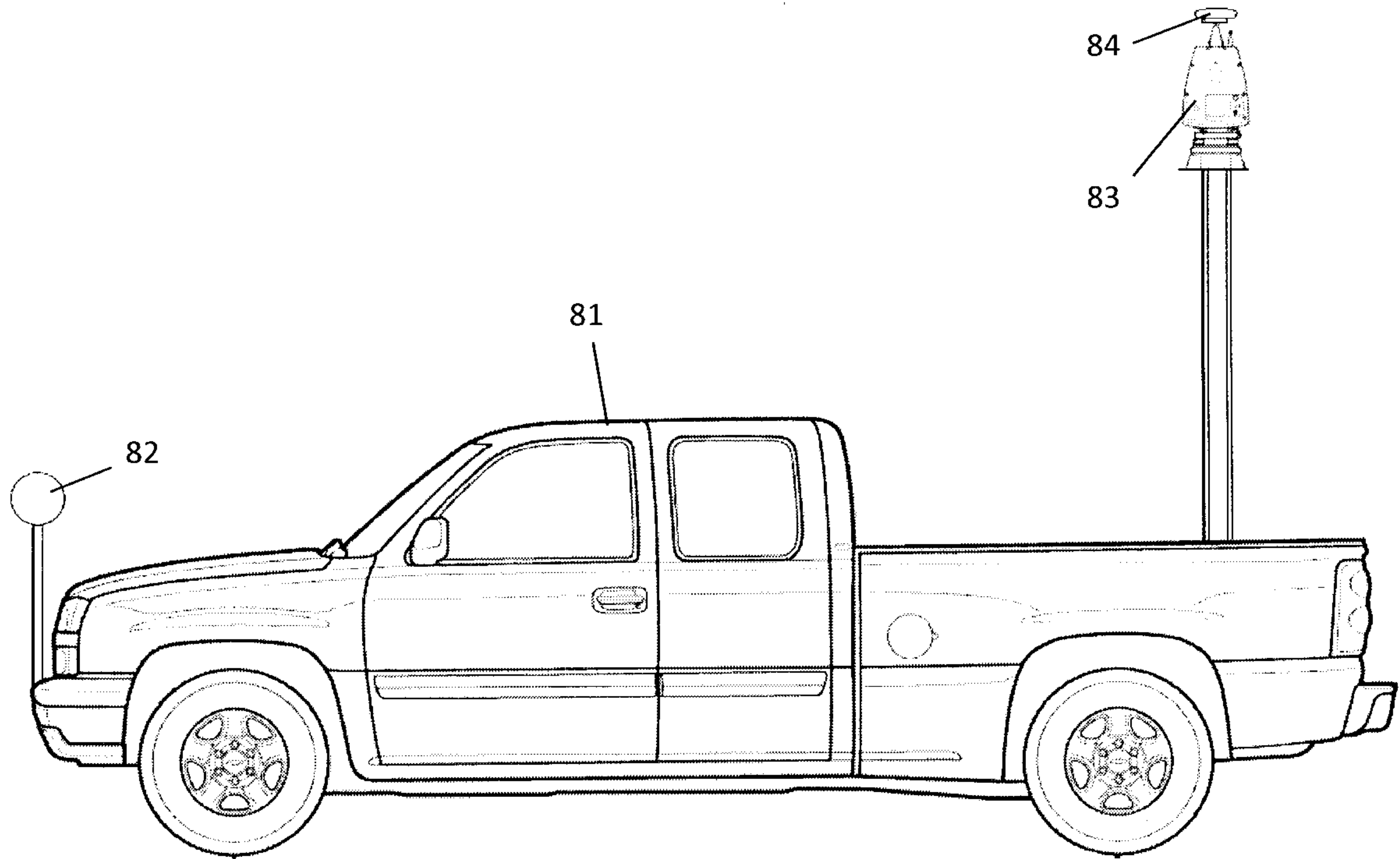


Figure 8

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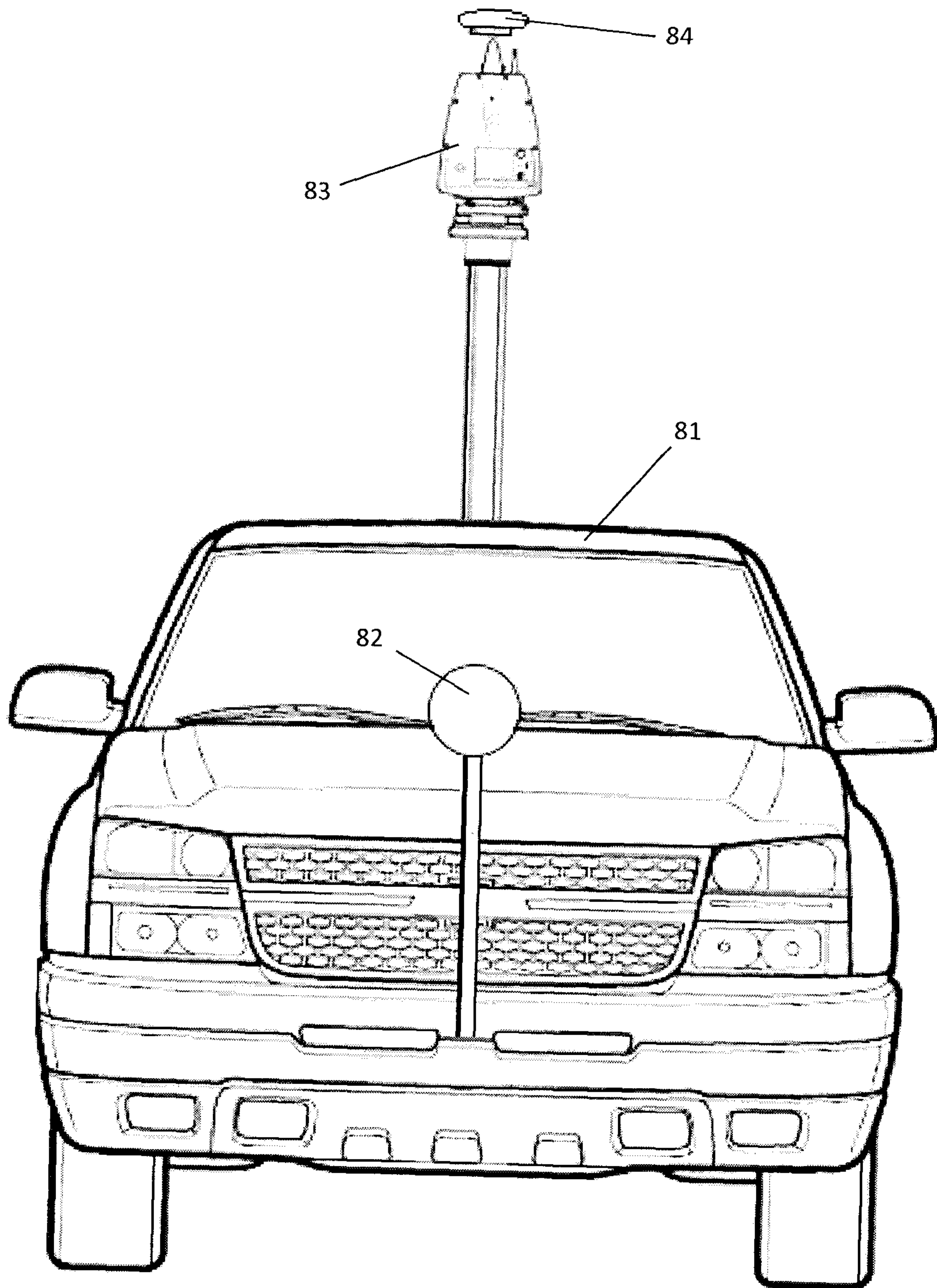


Figure 9

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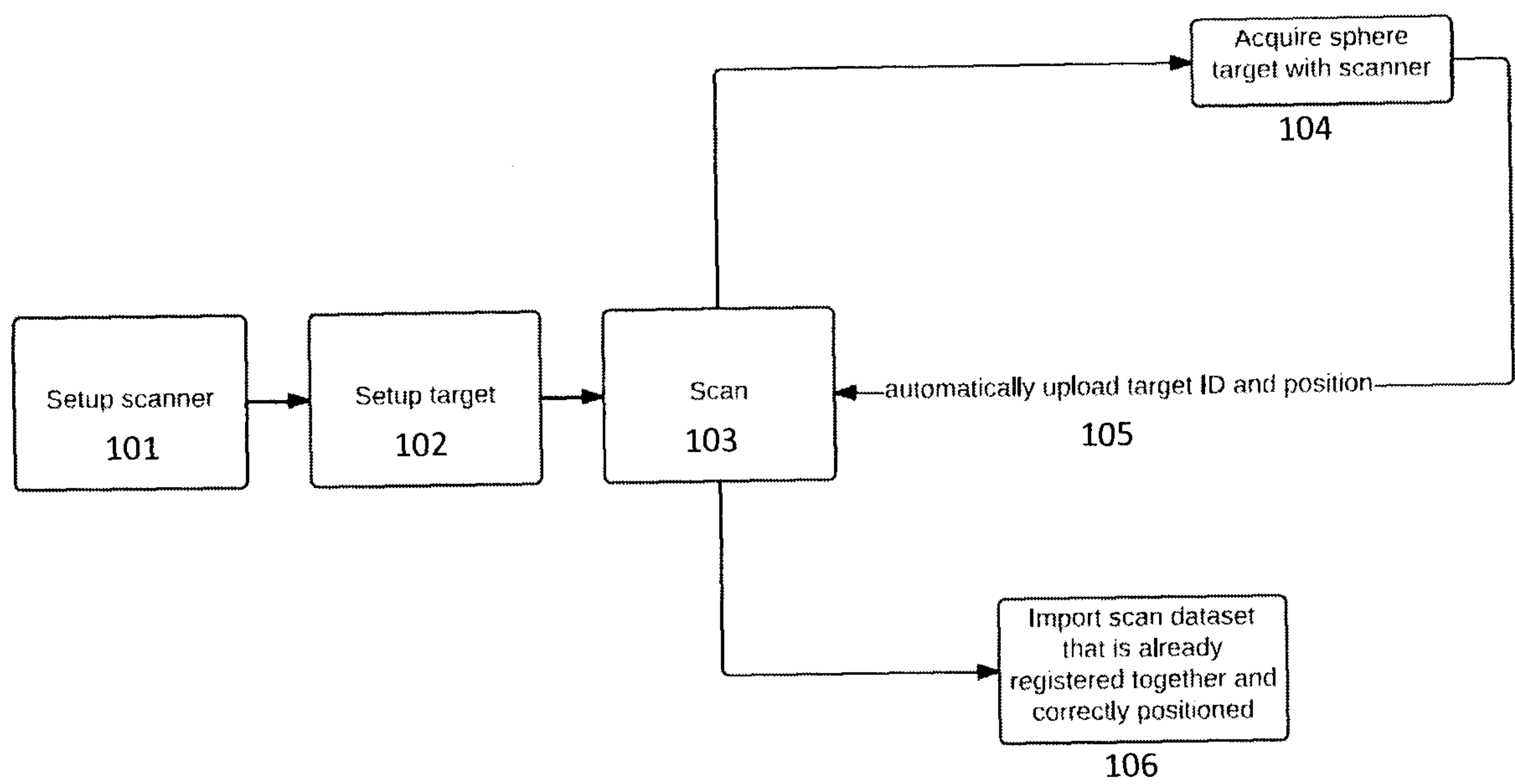


Figure 10

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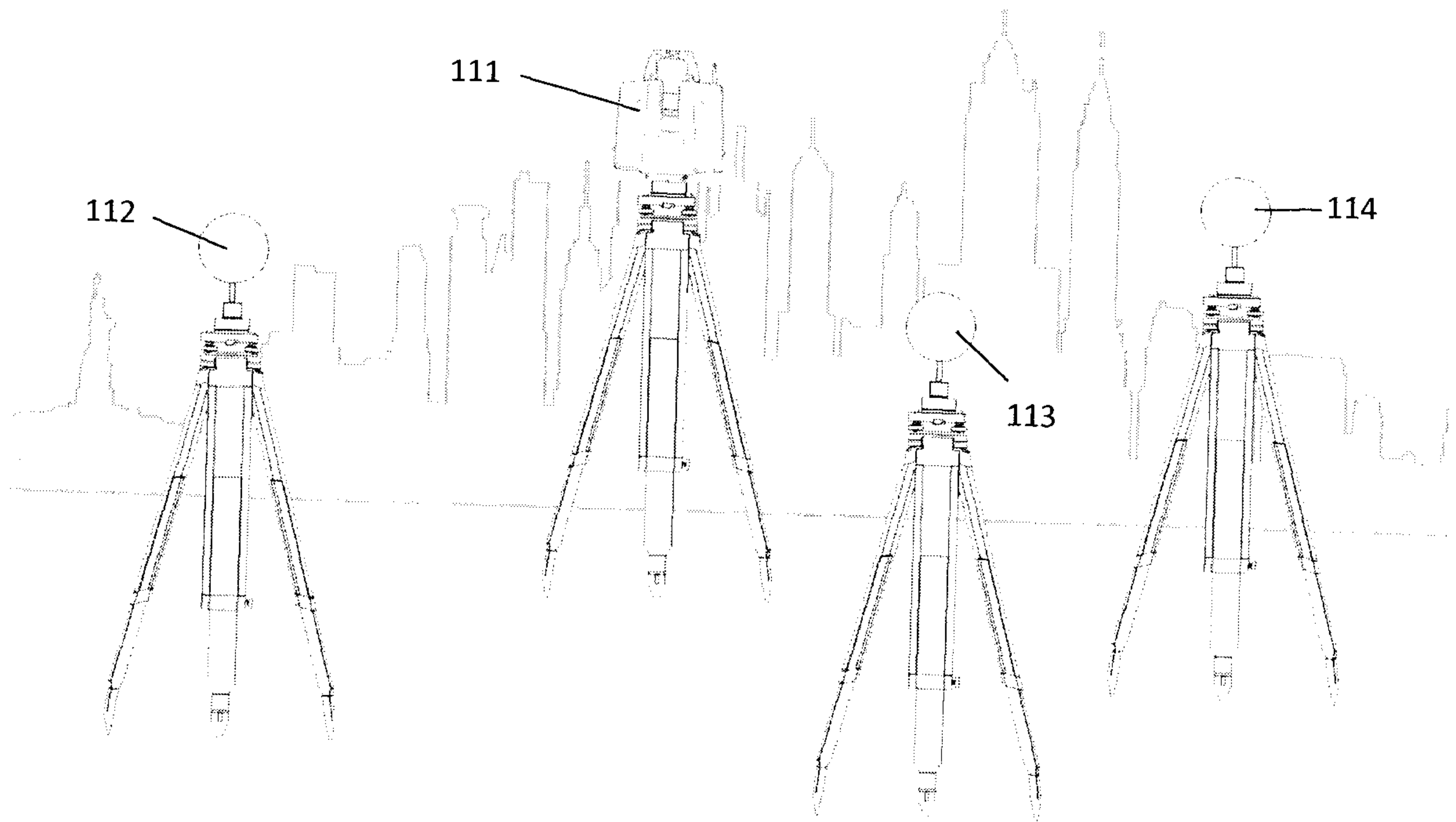


Figure 11

