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- (71) Applicant: ISRAEL AEROSPACE INDUSTRIES LTD.
[IL/IL]; Ben-Gurion International Airport, 7010000 Lod (IL).
- (72) Inventor: AHARON, Yifrach; 19 Ayalon Street, 7861619 Ashkelon (IL).
- (74) Agent: HAUSMAN, Ehud; Reinhold Cohn And Partners, P.O.B. 13239, 6113102 Tel-Aviv (IL).
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- (54) Title: LEVELING OFFSET METER AND METHODS OF USE AND CALIBRATION

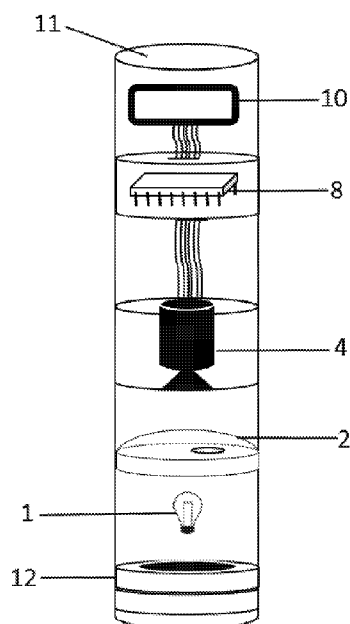


Fig. 1

(57) Abstract: A leveling offset meter (LOM) that includes a spirit level having one or more bubbles adapted for movement in two mutually orthogonal planes. An imager configured to image the one or more bubbles and store corresponding image data. A processor/CPU coupled to the imager and responsive to the image data for determining respective angular offsets to the vertical of the bubble in two mutually orthogonal horizontal planes, and means for conveying the angular offsets to a display unit.

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Leveling Offset Meter and Methods of Use and Calibration

FIELD OF THE INVENTION

The present invention relates to the field of inertial acceleration direction and more specifically to method to measure the direction of gravitational acceleration.

5 BACKGROUND OF THE INVENTION

In several fields of application the measurement of the direction of the gravitation and level planes is important. Typically spirit levels, bubble levels a plum bob or a plummet are used for such. The so-called "bull's eye level" is a circular, flat-bottomed device with the liquid under a slightly convex glass face with a circle at the center. It serves to level a surface across a plane, while the tubular level only does so in the direction of the tube. However, these instruments are for visual determination of the direction of gravitation, and typically are used to align devices and structures to a horizontal or vertical plane.

SUMMARY OF THE INVENTION

15 It is an object of the present invention to provide an accurate, machine readable, quantitative meter for the measurement of the angular offset in two angles of a surface from the vertical or horizontal plane. It is therefore called a leveling offset meter, or LOM.

According to one aspect of the present invention there is provided a leveling
20 offset meter (LOM) comprising:

at least one spirit level having one or more bubbles adapted for movement in two mutually orthogonal planes;

at least one imager configured to image the one or more bubbles and store corresponding image data;

25 a processor/CPU coupled to the imager and responsive to said image data for determining respective angular offsets to the vertical of the bubble in two mutually orthogonal horizontal planes; and

means for conveying the angular offsets to a display unit.

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According to another aspect of the invention there is provided method for measuring two angular offsets to the vertical in two mutually orthogonal horizontal planes, said method comprising:

imaging at least one spirit level having one or more bubbles adapted for
5 movement in two mutually orthogonal planes and determining respective angular offsets of the bubble from a calibrated zero reference.

The device and method according to the invention allow precise measurement of differences in directional alignment (e.g. orientation) between the leveling offset meter and a vertical that may, in some applications, be constituted by a local gravitational
10 force (or more generally any sufficiently slowly varying inertial acceleration force affecting the displacement of the spirit level's bubble (hereinafter "the bubble"), from its center leveled position) thus quantifying the two-axis angular offset from the level plane.

In further detail, a processor/CPU is used to calculate the position of the bubble
15 on each of the two angular axes on a plane parallel to the liquid surface of the spirit level and, by further calculations, derive the tilt of the leveling offset meter in two separate axes;

Furthermore the processor/CPU can also process images of two or more spirit levels simultaneously thus calculating the position of two or more bubbles and deriving
20 the orientation of the leveling offset meter in three separate axes.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

25 **Fig. 1** is an internal view, of an embodiment of an LOM as an independent measurement system;

Fig. 2 is an outside view, of an embodiment of an LOM as an independent measurement system;

Fig. 3 is an internal view, of an embodiment of an LOM as a part of a larger
30 system;

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Fig. 4 is an outside view of an embodiment of an LOM as a component of a larger system and an outside view of an embodiment of the invention as a component designed for direct soldering into a circuit board;

Fig. 5 is an internal view of an embodiment of an LOM consisting of more than one spirit levels and more than one imager;

Fig. 6 is a view of the reference point image and side view of its corresponding geometry and force applied on the device; and

Fig. 7 is a view of an arbitrary instance where the device is offset from the horizontal plane showing the image representation and the corresponding geometry and force applied on the device.

DETAILED DESCRIPTION OF EMBODIMENTS

The figures are intended to aid in understanding the invention and components illustrated therein are not necessarily drawn to scale.

In many instances, the same reference numbers may be used for similar components, despite modifications thereto, in the various embodiments described below. For the sake of brevity, description details of certain components which are known in the art are not necessarily included.

The Figures show a leveling offset meter (LOM) in accordance with embodiments of the invention. The LOM includes a bull's eye spirit level 2 or a plural number of tubular spirit levels 2 and 3 that are perpendicular to each other or disposed in another known relative orientation.

Also included are one or more imagers or cameras 4 configured to produce images 30 and 31 of the bubble of the spirit levels, including its boundaries and some of the surrounding fluid and any measurement markings on the spirit level's top window. Also, the spirit level can be illuminated by various methods such as using natural ambient light or by utilizing different illumination apparatus, for example adding a light emitting component 1 or any other apparatus that will ensure illumination of the spirit level.

The image 31 (Fig. 7a) of the bubble at any instance is compared to a fixed reference point 22 (Fig. 6b), stored in the processor/CPU memory as a pixel position, representing the position of the bubble when perpendicular to the vertical 26 in two

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mutually orthogonal horizontal planes. Reference point 22 is calibrated during the manufacturing process and stays constant and unique for each device, as long as the distance and orientation between the camera 4 and the spirit level 2 is constant.

Calculation of the angular offsets from the level plane is done by the
5 processor/CPU 8 which first measures the distance 20 between the current position of the bubble 21 in image 31 to the reference point 22 in image 30, and then applies a conversion algorithm using calibrated parameters thus converting the distance 20 to the tilt angle 24 representing the angle between a plane 25 perpendicular to the vertical 26.

The resulting calculations of the offset angle from the level plane 24 are
10 constantly streamed out of the device as required. The leveling offset meter (LOM) maybe a standalone device 11 or may be employed as a part 33 of a larger system (Fig. 4a), or it may be constructed as a component 35 (Fig. 4b) to be directly soldered onto a printed circuit board. Other configurations may also be possible.

For the different embodiments the power supply can vary and may include a
15 built in power supply 12, via a power connector 17 or any other apparatus or method for supplying power. Signals representing the output measurement may be conveyed as a digital output stream to a visual display screen 10 or to an output connector for connecting to an external device. Such an output connector can include a serial data connector 15, pins 18 for printed circuit board holes or any other suitable connector for
20 transferring the digital output into readable form.

The invention also provides a method for calibrating the LOM. This is performed by placing the LOM on an accurately rotating table. Rotating the LOM with a bull's-eye bubble through a full 360° causes the bubble to circumscribe a complete circle. The center of the circumscribed circle is the accurate position of the zero-offset
25 direction of the vertical reference. Such operation can be repeated with known angular offsets from the level plane of the rotating table to calibrate for different offsets from the reference zero: the outline of a circle circumscribed by the bubble at a given angular offset corresponds to the quantitative value of the angular offset from the zero-offset direction.

30 In summary, an imager images the position of the bubble 21, and a processor/CPU 8 calculates the distance between the bubble's current position 21 and a reference position 22 (stored in the processor/CPU memory) and finally converts the

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distance value to two offset angles from the level plane based on a conversion algorithm and calibrated parameters. Different embodiments allow the invention to be used either independently as a handheld device 11, or as an integration component 33 to be added to a larger system by simple connector integration or as an electrical component 35
5 soldered into a circuit board.

It should be understood that the above description is merely exemplary and that there are various embodiments of the present invention that may be devised, *mutatis mutandis*, and that the features described in the above-described embodiments may be used separately or in any suitable combination.

10 It will also be understood that the processor according to the invention may be a suitably programmed computer. Likewise, the invention contemplates a computer program being readable by a computer for executing the method of the invention. The invention further contemplates a machine-readable memory tangibly embodying a program of instructions executable by the machine for executing the method of the
15 invention.

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CLAIMS:

1. A leveling offset meter (LOM) comprising:
 - at least one spirit level having one or more bubbles adapted for movement in two mutually orthogonal planes;
 - 5 at least one imager configured to image the one or more bubbles and store corresponding image data;
 - a processor/CPU coupled to the imager and responsive to said image data for determining respective angular offsets to the vertical of the bubble in two mutually orthogonal horizontal planes; and
 - 10 means for conveying the angular offsets to a display unit.
2. The LOM according to claim 1 where the at least one spirit level is a bulls-eye spirit levels.
3. The LOM according to claim 1 where the at least one spirit level is a plum bob.
4. The LOM according to any one of the preceding claims further incorporating an
15 illumination device for illuminating the spirit level so as to improve the image contrast.
5. A method for measuring two angular offsets to the vertical in two mutually orthogonal horizontal planes, said method comprising:
 - imaging at least one spirit level having one or more bubbles adapted for movement in two mutually orthogonal planes and determining respective angular
 - 20 offsets of the bubble from a calibrated zero reference.
6. The method according to claim 5, further including conveying data representative of the respective angular offsets to a display unit.
7. A method for calibrating the leveling offset meter (LOM) according to any one of claims 1 to 4, the method comprising:
 - 25 placing the LOM on a flat table;
 - rotating the table and the LOM through a full circle while recording the position of the bubble that circumscribes a full circle; and

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successively tilting the LOM at a series of known angles from the level plane of the flat table and repeating the rotation so as to circumscribe a plurality of circles each at known offset angles for subsequent use to obtain a quantitative measurement of the two-angular axes offset from the direction to the vertical of the bubble.

- 5 **8.** A computer readable memory storing data representative of program code, which when run on a suitable computer causes the computer to carry out the method of claim 5 or 6.

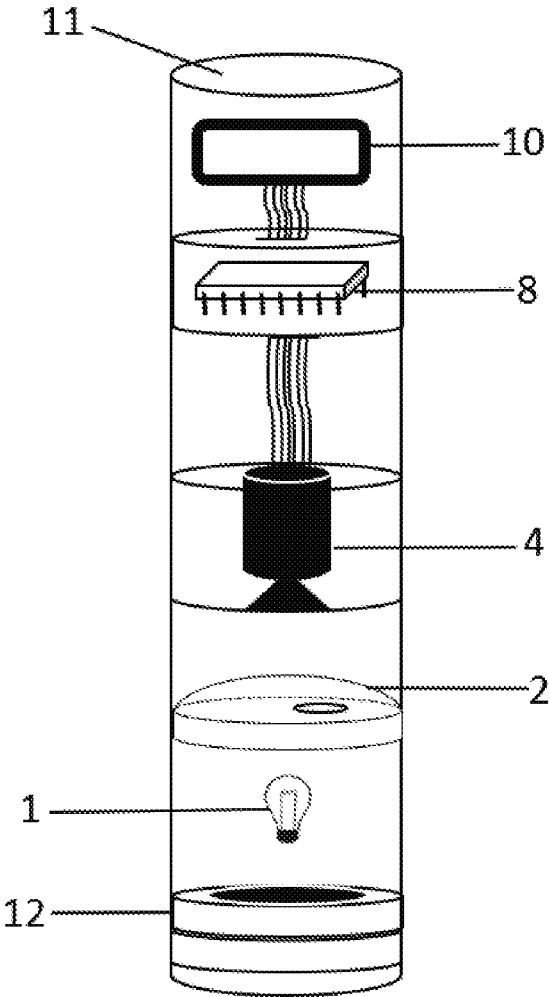


Fig. 1

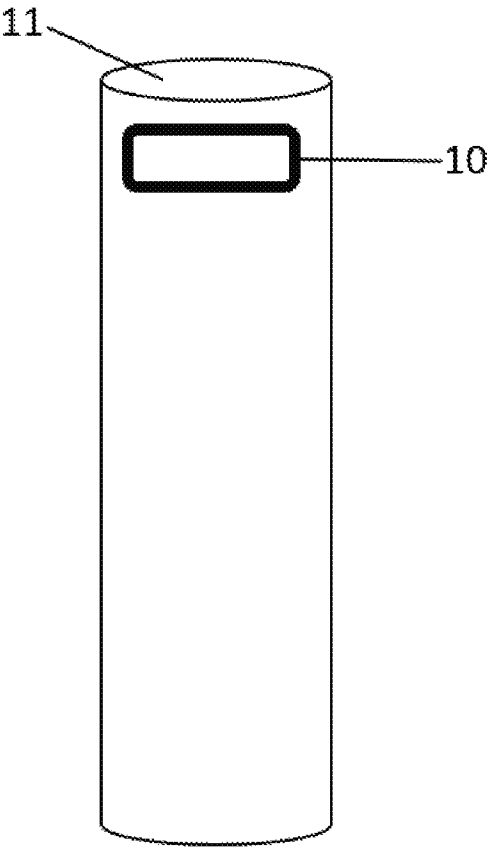


Fig. 2

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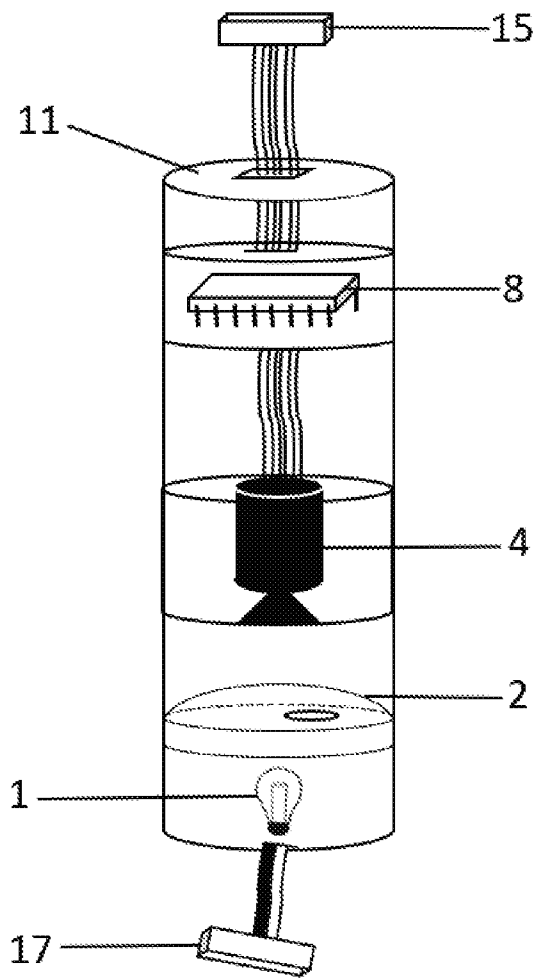


Fig. 3

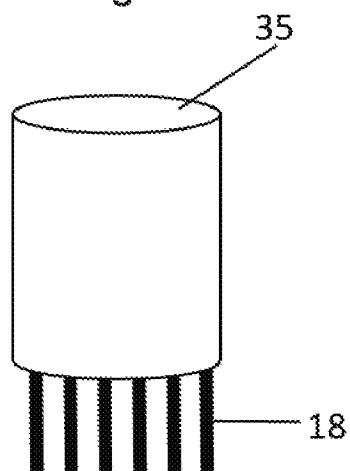


Fig. 4b

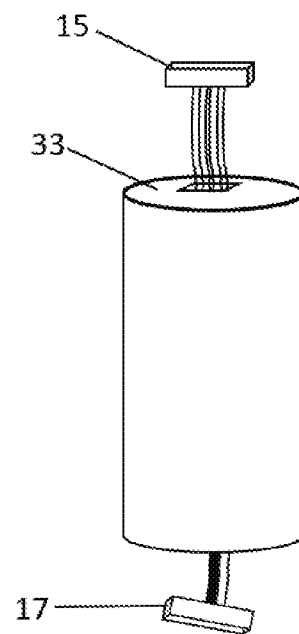


Fig. 4a

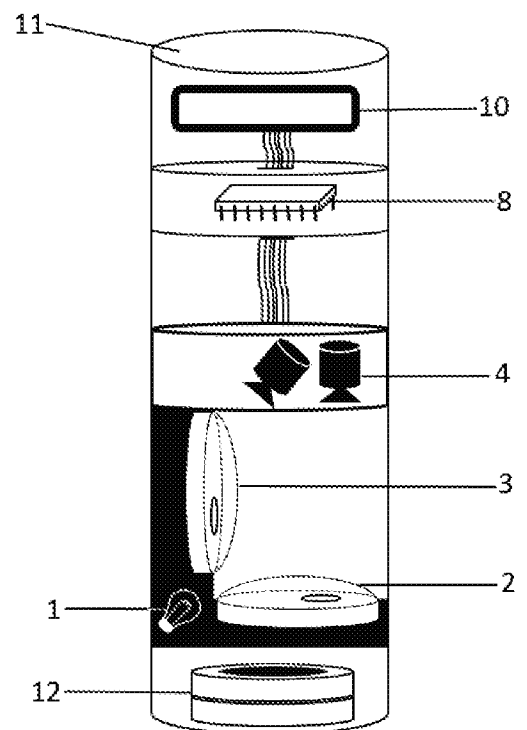


Fig. 5

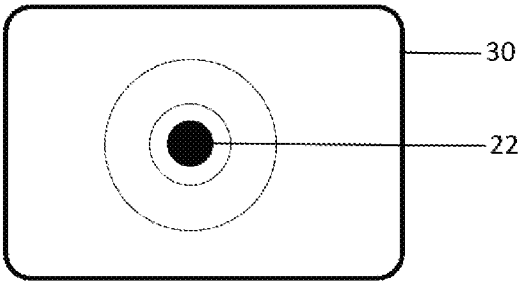


Fig. 6a

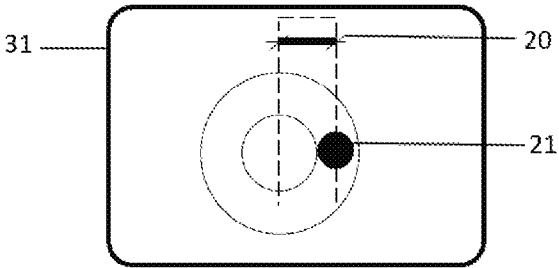


Fig. 7a

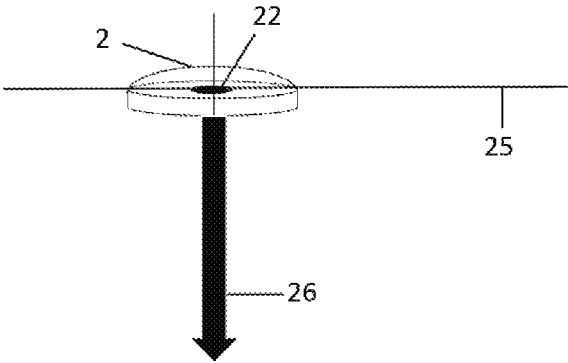


Fig. 6b

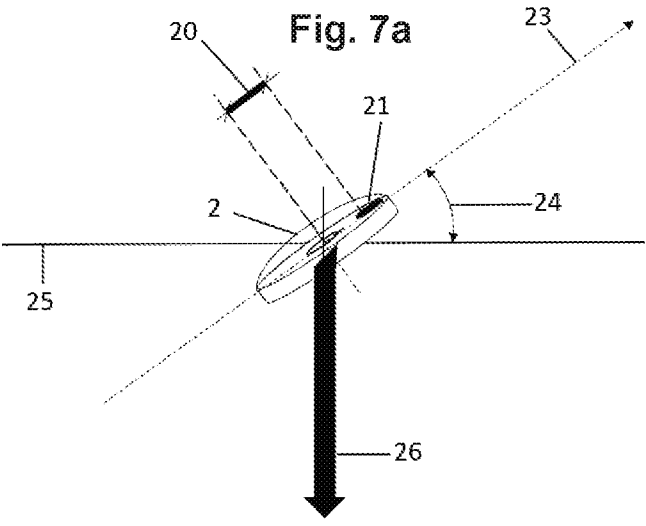


Fig. 7b

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2016/050269

A. CLASSIFICATION OF SUBJECT MATTER

IPC (2016.01) G01C 9/36, G01C 9/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (2016.01) G01C 9/36, G01C 9/06

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)

Databases consulted: THOMSON INNOVATION

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6647634 B2 YANG SUE-ZENG 18 Nov 2003 (2003/11/18) the entire document	1-6,8
Y	the entire document	7
X	US 5101570 A SHIMURA KIKUO 07 Apr 1992 (1992/04/07) the entire document	1-6,8
Y	the entire document	7
X	JP S60252215 A SUGAWARA SABUROU 12 Dec 1985 (1985/12/12) abstract and figures	1-6,8
Y	abstract and figures	7

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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“&” document member of the same patent family

Date of the actual completion of the international search

17 May 2016

Date of mailing of the international search report

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Name and mailing address of the ISA:

Israel Patent Office

Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel

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Authorized officer

NARGASI Ayelet

Telephone No. 972-2-5651620

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2016/050269

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2013250189 A UNIV IBARAKI 12 Dec 2013 (2013/12/12) abstract and figures	1-6,8
Y	abstract and figures	7
Y	US 6993849 B1 CAMPBELL RAY F 07 Feb 2006 (2006/02/07) the entire document	7

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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