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(54) **DEVICE, AND RELATED METHOD, FOR DETERMINING THE DIRECTION OF A TARGET**

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(57) **ABSTRACT**

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The invention concerns the field of sighting or aiming means and more particularly a device (1) for determining the direction of a target in a predefined frame and of the type having sighting means (10), means having a sighting member (13), three gyrometers (14₁, 14₂, 14₃) arranged along three axes in different planes, means for control (16), means (20) for resetting said sighting means (10) and means (30) for processing signals derived from the sighting means (10), said processing means being capable of determining the direction between the sighting means (10) and the target and of transmitting it to imaging means or to external means, and also means (16) for controlling the transmission to the imaging means (40) or to external means, of representative values of the direction between the sighting means (10) and the target, this device being characterized in that the resetting means comprise at least one non gyroscopic sensor (17) arranged on the sighting means (10) and capable of emitting a signal for its transmission to the said processing means.

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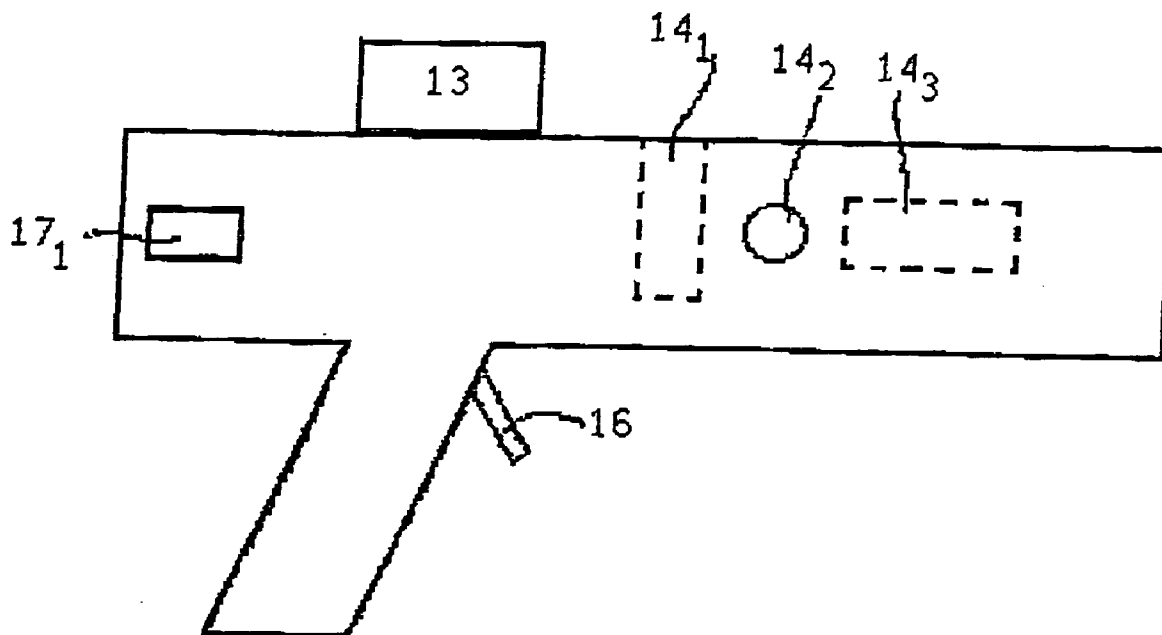
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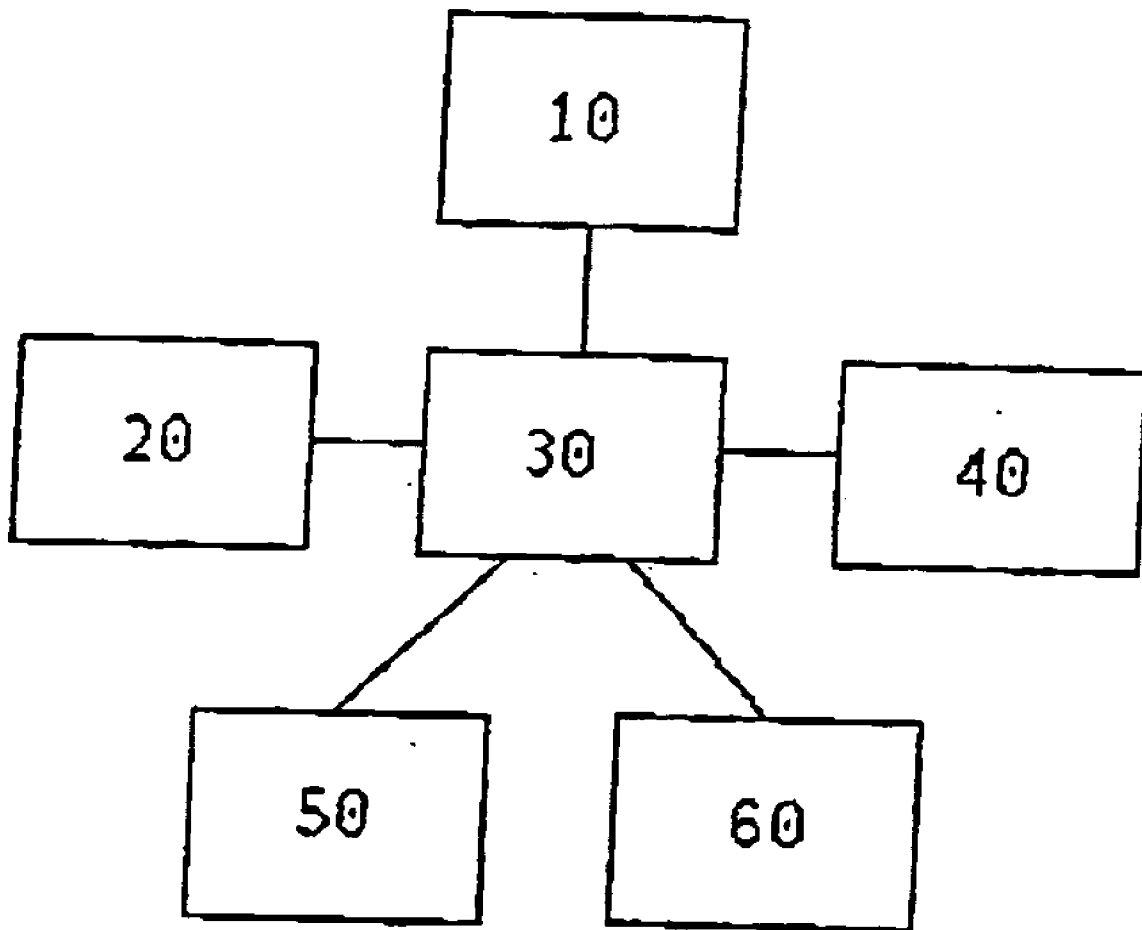


FIG. 1

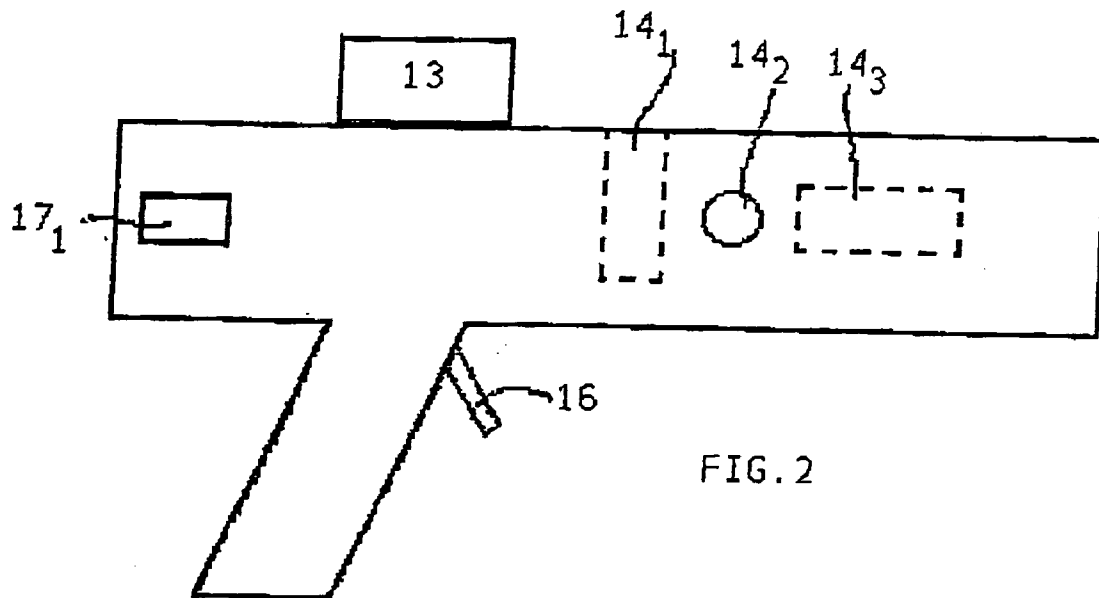


FIG. 2

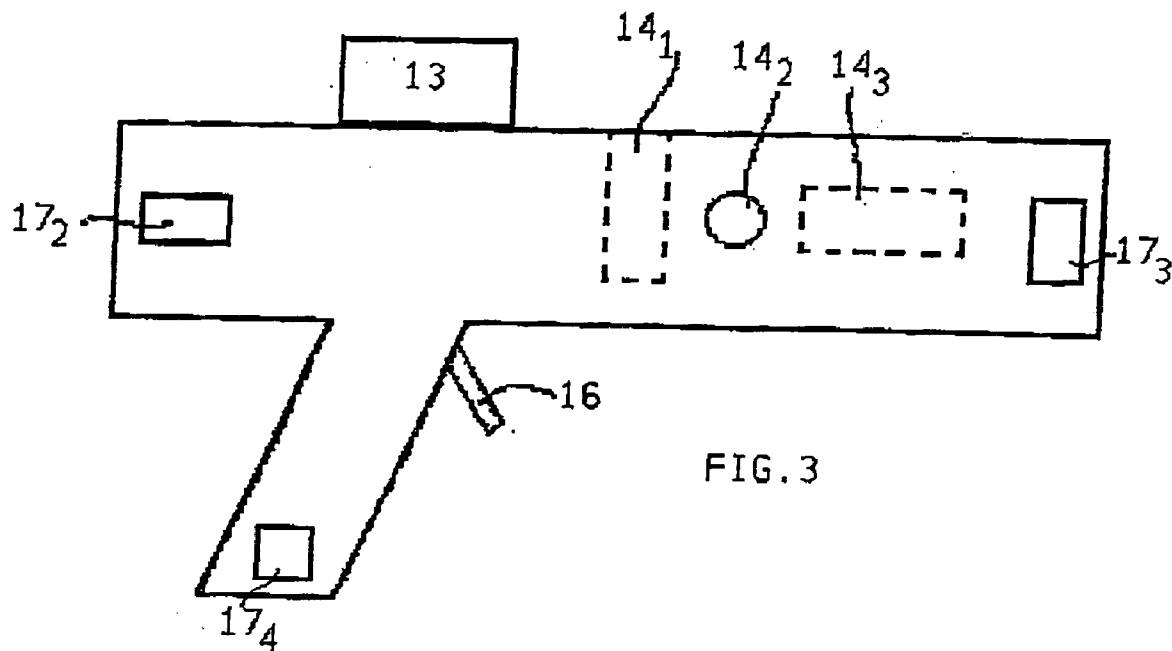


FIG. 3

DEVICE, AND RELATED METHOD, FOR DETERMINING THE DIRECTION OF A TARGET

[0001] The present invention concerns the field of sighting or aiming instruments. Its subject matter is more particularly a mobile device capable of determining position, kinematics and identification data of a target in a predefined or geographic frame, said device having sighting means and means for processing signals derived from the sighting means. The said processing means being capable of determining position, kinematics and identification data of the target and transmitting them to external means.

[0002] Numerous devices exist which are capable of determining, in particular, the elevation and the azimuth of a target.

[0003] EP 5575591 may be mentioned in this context: it describes a device capable of determining the orientation of an object with respect to a reference orientation, and comprises a movable orientation unit and a reference sensor unit, each one of them having a three-axis gyroscopic unit, a calculation unit receiving measured values from the aforesaid units, and an output unit.

[0004] However, many of these devices require substantial logistics, while in certain circumstances it may prove necessary or indeed vital to use a lightweight and manageable device that can be used by a single operator.

[0005] Such devices exist, and utilize magnetic field sensors.

[0006] Among these devices, the binoculars sold under the LEICA trade name, which utilize magnetic field sensors and an active rangefinder, are capable of determining the elevation and the azimuth of a target, and give complete satisfaction when used outdoors. Their utilization suffers, however, of some redhibitory limitations for specific utilizations. They cannot be used in an environment having magnetic disturbances, and on the other hand, the speed and the accuracy of the measured values are very limited.

[0007] Other devices consist in analyzing electrostatic or electromagnetic fields, and by reading their cartography, determining the position and direction of a target.

[0008] The devices are satisfactory in environments that are completely known of small dimensions. They are difficult to be utilized and do not tolerate changes in the electrical environment.

[0009] Also known is U.S. Pat. No. 4,012,989, which describes a helicopter having a device for determining the direction of a target so as to direct a movable weapon system. The device for determining the direction of a target has a movable sighting member equipped with two integrated inertial gyroscope, resetting means integral with the helicopter equipped with two gyroscopes and means for slaving the direction of the weapon as a function of the data supplied by the gyroscopes. The resetting means serve to immobilize the four gyroscopes in a first reference position to define a frame of reference. When the sighting means are disengaged from the resetting means, the four gyroscopes are released. The gyroscope pair integrated with the resetting means rotates as a function of the movements of the helicopter and the movements of the gunner movement handling the sighting member. The weapon is directed in real-time toward the target as a function of the difference in rotation between the two gyroscopes.

[0010] This device has numerous drawbacks. For example the gunner is obliged to keep the sighting unit continuously pointed toward the target until the weapon system is fired, which limits firing capabilities and makes the helicopter vulnerable if multiple targets are present. Because of helicopter vibrations and of uncontrolled wrist movements, the two gyroscopes of the sighting means transmit to the processing means sequences of signal changes which cause an accumulating measurement error, which impairs the accuracy with which the target direction is determined. On a ship, if the sea is rough and thus with severe pitching and rolling, it would be almost impossible to orient the weapon system toward the target with such a device.

[0011] One of the purposes of the invention is to propose a lightweight and manageable device capable of accurately and rapidly determining the elevation and the azimuth of a target, and usable regardless the type of environment.

[0012] Also known is patent FR 9 700 497, which describes a device capable of determining the direction of a target in a predefined frame of reference, and of the type having sighting means including a sighting member and controlling means, means for resetting those sighting means, and means for processing signals coming out from this sighting means, those processing means being capable of determining the representative values of the direction between the sighting means and the target and transmitting them to imaging means or to external means ; the device being characterized in that the sighting unit have moreover three gyrometers arranged along three axes that are substantially perpendicular to one another, and means for controlling the transmission to the imaging means or external means, of values representing the direction between the sighting means and the target.

[0013] This device requests physical resetting means which are often difficult to utilize and which have a major drawback for some applications.

[0014] The solution proposed is a device capable of determining the direction of target in a predefined frame of reference, and of the type having sighting means, means utilizing a sighting member, three gyrometers arranged along three axes located in different planes, means for resetting those sighting means and means for processing signals derived from the sighting means, those processing means being capable of determining the direction between the sighting means and the target and transmitting the value to imaging means or to external means, and also controlling means for the information to the imaging means or to the external means, representative values of the direction between the sighting means and the target, the device being characterized in that the resetting means have at least one non-gyroscopic sensor located in the sighting means and capable of emitting a signal for its transmission to the aforesaid processing means.

[0015] The said at least sensor, according to a particularly advantageous characteristic, may be composed of a one axis inclinometer, or of at least two inclinometers.

[0016] According to another characteristic the said at least sensor has an electronic image sensor. For its operation, the electronic image sensor is capable of generating a signal representative of images, this signal being transmitted to processing means, these means being capable of determining the position of a pattern inside the said images.

[0017] According to an additional characteristic, the sighting means comprise an electronic image sensor and associated image-processing means capable of compensating the operator tremors, such as an image stabilizer.

[0018] According to another characteristic, the processing means of the sighting means are capable of compensating the operator tremors by use of the optical field of the electronic imaging sensor.

[0019] According to one characteristic, the processing means of the sighting means are capable of determining the angular field of the electronic imaging sensor from the relationship between the operator tremors derived from the signal coming from the electronic sensor and the one coming from the sighting means.

[0020] According to an additional characteristic, the processing means of the sighting means are capable of participating to the transmission of the identification features of the target and/or to the absolute direction of the sighting means and possibly to generate from the signals of the electronic sensor and of the sighting means, a signed image, which means that includes a space position and time (time stamped data, geographic position, attitude, distance of the aiming point . . .). These processing means may also rebuild the global landscape, from the signed images with the information of position of the different zones of this landscape. These images and/or the rebuilt landscape may also be then transmitted to imaging means or to external means.

[0021] According to another characteristic, the device comprises recording means for the signal coming from the electronic image sensor, and/or it comprises imaging means for the said images, as for some information such as the direction of the aimed target, its range and/or its type.

[0022] According to another characteristic, the said at least sensor is composed of at least two electromagnetic receivers. One electromagnetic emitter may be associated to this last.

[0023] According to another characteristic, the device according to the invention comprises three optical gyrometers, for example, optical fiber gyrometers.

[0024] According to another characteristic, the processing means include an electrical power supply and calculation and information management means, which utilize a software program that performs several functions, such as:

[0025] Target designation function, which causes data to be acquired from the sighting instrument and processes them to obtain the desired elevation and azimuth;

[0026] Transmission function, which sends the azimuth and elevation data for display on the imaging means and/or for the purpose of a weapon system;

[0027] Absolute position function, which allows correction at regular intervals of the sighting instrument's drift due to the use of gyrometers;

[0028] Imaging function, which displays the operational state of the elements according to the invention.

[0029] According to another characteristic the sighting means comprise the acquisition of the geographical position

by radio positioning means, for example satellite means such as the GPS and may include an active rangefinder.

[0030] According to another characteristic, the sighting means comprise at least two accelerometers and regarding the processing means include triangulation means capable to perform a discreet positioning.

[0031] According to an additional characteristic the sighting means comprise at least a magnetic sensor used to compensate the errors linked to the magnetic field of the gyrometers used and/or to make it possible to correlate the measurements as compared to the earth's magnetic field.

[0032] According to an additional characteristic, the sighting means comprise at least one accelerometer used to perform compensations of the errors due to the accelerations of the gyrometers used and/or to allow the calculation of the sighting means motion.

[0033] According to an additional characteristic, the sighting means comprise at least one inclinometer used for the inclination computation of the sighting means with respect to the terrestrial gravity field and/or for the correlation of the measurements.

[0034] According to an additional characteristic, the sighting means comprise transmission wiringless means aimed to suppress the cables between the different means.

[0035] According to an additional characteristic, the processing means comprise telecommunication means aimed, in particular, to send the acquired information to an Operation Center.

[0036] According to an additional characteristic, the sighting means include an active laser rangefinder.

[0037] According to an additional characteristic, the processing means comprise triangulation means in order to execute a discreet telemetry, this static triangulation able to be performed by many sighting units.

[0038] According to an additional characteristic, the processing means comprise triangulation means in order to execute a discreet telemetry, this dynamic triangulation able to be performed by a single sighting unit moving with a known kinematics.

[0039] According to a particular characteristic, a part of the acquisition means of the sighting means can be transferred to an other place, for example for weight or ergonomic reasons. According to an additional characteristic, the sighting means comprise at least a sensor of temperature used to perform compensations of the errors dependent on the temperature of the gyrometers used.

[0040] It is also known that the values emitted by gyroscopes drift, particularly in term of time, temperature and the magnetic field, and that they require static and dynamic calibration.

[0041] Patents EP 717 264 and EP 496 172 describe methods for correcting gyrometer biases and means for implementing them.

[0042] The former concerns the correction of gyrometer biases on an aircraft, and the latter on a vehicle. In both cases, gyroscopic calibration is performed when the aircraft or vehicle is a stationary position.

[0043] However to obtain a good accuracy, it is necessary to compensate the gyroscopic drift at all times and not just in a stationary position.

[0044] It is also known that a complex model of the gyroscopic data is needed to obtain good integration result. Signal processing means that are powerful and bulky, and thus not transportable, are used.

[0045] One of the purposes of the invention is to propose a method for processing the signals derived from gyroscopes which yields good results and doesn't require neither powerful signal processing means, nor mechanical resetting means.

[0046] The solution is a resetting process for a device capable of determining the direction of a target in a first predefined frame from the sighting means type, comprising a sighting member, three gyrometers arranged in three axis in different planes, and means to process the signals derived from the sighting means, these processing means being capable of determining the direction between the sighting means and the target; the process being characterized in that it comprises a step by which the processing means determine from the signal emitted by the said sensor and by those emitted by the gyrometers, the attitude of the sighting means in a second predefined frame, the former and the latter frames able to be identical or not.

[0047] According to one characteristic, the said second frame of reference is a terrestrial or geographic frame of reference with respect to an electromagnetic emitter or is a geographic frame of reference with respect to a pattern whose position doesn't change or changes a very little.

[0048] According to a particular characteristic, it comprises a step that determines on the one hand the direction of a line D1 parallel to the earth's rotation axis and going through point P where the sighting means (10) are, by processing the signals derived from the gyroscopes, and on the other hand, the direction of the vertical D2 of the location associated to point P, by processing the two signals derived from the said sensor.

[0049] According to an additional characteristic, it comprises an additional step that determines the geographic north direction, this direction being obtained by the intersection of the plane defined by the D1 and D2 line with the plane perpendicular to D2 and coming through P.

[0050] According to another characteristic of the process, whose utilization consists, on the one hand, of sighting means comprising at least three sensors, that is to say, three electromagnetic receivers, and on the other hand, of a device comprising an electromagnetic emitter, the process being characterized in that the processing means compute the position and the orientation, that is to say the attitude of the sighting means by processing the signals derived from the magnetic sensors and of the cartography of the magnetic field expected, which has been loaded before in the memory of the these processing means.

[0051] According to another characteristic of the process, whose utilization consists of sighting means composed of an electronic imaging sensor, such as a camera rigidly fastened to the sighting means, this camera generating a signal representative of the image observed, process wherein it uses a step that makes the imaging process capable of

determining the position of a pattern in the said image, the position of this pattern being known.

[0052] The solution is also a resetting process of a device capable of determining the direction of a target in a predefined frame of reference and of the type having sighting means, means having a sighting member, three gyrometers arranged along three axes in different planes, means for command, and means for processing signals derived from the sighting means, said processing means (30) being capable of determining the direction between the sighting means and the target, the said process being characterized in that it includes a step by which the processing means determine the value of the gravity vector either in a continuous process or in succession at T_0, T_1, T_i, T_n , of the signals sent by at least one non gyroscopic sensor, arranged on the sighting means.

[0053] According to an additional characteristic, it comprises a step by which the processing means compute the K, T and R angles, defined as follows:

[0054] Knowing that:

[0055] P is the point of the earth surface where the sighting means are;

[0056] $R_T(X_t, Y_t, Z_t)$ is a reference frame associated to point P and connected to the earth, the X_t axis being the horizontal West to East axis oriented towards East, the Y_t axis being the horizontal South to North axis oriented towards North, and the Z_t axis being the vertical axis oriented upwards.

[0057] $R_{MV}(X_s, Y_s, Z_s)$ is a reference frame connected to the sighting means integrating the three gyrometers and the said at least one non gyroscopic sensor,

[0058] the successive rotations of a $-K$ angle about Z_t axis, then of a $-T$ angle about the axis resulting from the previous rotation applied on the X_t axis, then of a $-R$ angle about the axis resulting from the two previous rotations, applied on Y_t axis, put the reference frame R_T on the R_{MV} frame of reference.

[0059] According to an additional characteristic, it comprises a first step consisting in the calculation of the expression of the $R_T(T_i)$ frame of reference into the $R_{MV}(T_i)$ frame of reference, through the implementation of the following rotations:

[0060] the rotation of a α -angle, which is a function of elapsed time between instants T_0 and T_i

$$\left(\frac{\alpha}{T_i - T_0} = 15^\circ/h\right)$$

[0061] about the pole axis oriented from the South to North, that is to say, around the rotation axis of the earth, and which is only a function of point P latitude where the sighting means are, in the frame of reference $R_T(T_0)$ or $R_T(T_i)$,

[0062] the angles of rotation $-K, -T$, and $-R$ mentioned above,

[0063] the rotation, which results from, the integration of the incremental angles measured by the gyrometers.

[0064] Then in a second step, which consists in determining K, T, and R angles, either by an inversion process of the equalization made of the computed and of the measured values of the gravity vector, or by a minimization process of the error function, by use of an algorithm aimed to seek the minimum value of a function of many parameters calculated on a sample of data, for example, by use of an algorithm of simple down hill type or of simulated annealing type, or by use of any one of dedicated algorithms, such as quadratic programming of Karmakar, More and Toraldo. These kinds of algorithms are described in the book called Numerical recipes C—2d Ed—W.H. Press and AL,—Cambridge University Press 1998.

[0065] This second step may include as well the computation of the latitude of point P where the sighting means are located.

[0066] The solution may also propose, as a complement, an integration process of the gyroscopic data wherein it consists in performing in succession, based on gyroscope values obtained between a time T_0 and a time T_1 , first calculations utilizing a complex model, which, given the processing capacity, cannot function in real time, due to power but does yield accurate results, and then based on gyroscope values obtained between a time T_0 and a time T_1 , second calculations using a simplified model that can be implemented in real time.

[0067] According to another characteristic, the software program performs also a function of correcting the drift of the gyrometers by use of a model of their drift in the long term between successive measurements.

[0068] According to another characteristic, the software program performs also a function of correcting the drift of the gyrometers by use of a model of the earth's magnetic field between successive measurements.

[0069] According to another characteristic, the software program performs also, an automatic calibration by use of a model that corrects the drift of the gyrometers with respect to the temperature between the successive measurements.

[0070] According to another characteristic, the sighting means comprise at least a temperature sensor used to compensate the errors due to the temperature of the gyrometers used.

[0071] According to an additional characteristic, the sighting means have at least one temperature sensor used to compensate the errors related to the temperature of the gyrometers used.

[0072] Other advantages and characteristics will become evident from the description of a particular embodiment in the context of operation aboard a ship, but which may also appear ashore or on board an aircraft, and with reference to the attached drawing in which:

[0073] FIG. 1 shows a diagram of the general means according to the invention;

[0074] FIG. 2 depicts sighting means according to a first kind of embodiment of the invention;

[0075] FIG. 3 illustrates sighting means according to a second kind of embodiment of the invention.

[0076] The means according to the invention depicted in FIG. 1 have sighting means 10, resetting means 20, signal processing means 30, imaging means 40, and external means 50, 60.

[0077] As shown in FIG. 2, sighting means 10 have means 11 in the shape of a pistol. Barrel 12 thereof is a precision support of lightweight material, for example fiber carbon, on which are positioned on the one hand a sighting member 13, and on the other hand, along three axes which are substantially perpendicular to one another, three optical gyroscopes 141, 142, 143. Preferably these gyroscopes are fiber-optic gyrometers. They allow a highly accurate measurement to be obtained, exhibit low drift, withstand rapid motion, and can be used in any environment.

[0078] These gyrometers 14₁, 14₂, 14₃ output the rotation velocity about their axes, and make it possible, by step-by-step integration over time, to determine the position of means 11.

[0079] Sighting member 13 is constituted by a sight that projects a reticle at infinity, thus allowing sighting without parallax error.

[0080] Orifices are machined into the pistol to house the electrical system and the three measurement gyrometers therein. The plane surfaces on which they rest and which determine their axes of rotation are machined to ensure they are perfectly perpendicular. These sighting means additionally have transmission control means constituted by a switch 16 in the form of a pistol trigger.

[0081] These sighting means have also at least a sensor 17 which belongs to the resetting means. This sensor may notably be constituted by a two axes inclinometer or at least two inclinometers, or at least one accelerometer, or at least two low frequency magnetic receivers, or by an electronic imaging sensor.

[0082] Processing means 30 are portable and have a stabilized power supply and calculation and information management means that utilize a software program that performs several functions.

[0083] The external means comprise on the one hand means 50 for measuring the attitude (heading, roll, pitch) of the ship, in this case a navigation unit, and the latitude of the latter on the surface of the earth. In this exemplifying embodiment, these data are transmitted to the means according to the invention by the ship's navigation means by way of a transfer function, in the form of data that can be utilized directly by the calculations means, to take into account the position of the navigation unit with respect to the resetting means.

[0084] They also comprise a weapon system 60, the aiming of which is controlled on the basis of the elevation and the azimuth values determined by the means according to the invention, and of values pertaining to the weapon system and its location on the ship.

[0085] In the context of the invention, it is sufficient to determine the attitude of the sighting instrument in order to designate the target and thus to determine the direction from sight to target.

[0086] This attitude can be expressed in various frames of reference depending on the needs of the system that will process the sighting information.

[0087] In this embodiment of the invention, the frame of reference considered as a terrestrial frame whose axes are the vertical of the location, geographic North, geographic East or West as stated hereafter in the framework of the resetting algorithmic function performed by resetting means 20.

[0088] The resetting algorithmic function that allows correcting periodically the drift of the sighting instrument due to the use of gyrometers, can be performed in different ways.

[0089] According to a first mode of implementation, it is only performed by processing of the signals derived from three gyrometers 14₁, 14₂, 14₃ arranged along a trihedron resting on the sighting 10 and derived from a two axes inclinometer arranged on the sighting means and whose position is known in the said trihedron. The resetting function is performed when the sighting means are at rest. It shall be noted that this function can also be performed when the sighting means are moving according to any trajectory as described later.

[0090] The software program of the processing means 30 analyses continuously each signal derived from each gyrometer 14₁, 14₂, 14₃ and when the rest position of the sighting means is detected, a subroutine determines, in the frame of reference constituted by the said trihedron, in the one hand by processing the signals derived from the gyroscopes, in a continuous process, the direction of a line D1 parallel to the earth's rotation axis and passing through P where the sighting means 10 are located, and on the other hand the direction of the vertical linked to point P, by processing the two signals derived from the inclinometer.

[0091] The meaning of vertical of the location associated to point P is the line passing through this point and the geographic terrestrial center.

[0092] Knowing the direction of line D1 parallel to the earth's rotation and passing through point P and also the direction of D2 of the vertical linked to point P, the software program of the processing means elaborates, in a frame of reference formed by this trihedron, a terrestrial invariant frame of reference in which the origin is constituted by the position of the sighting means, while:

[0093] The first axis is composed by line D2;

[0094] The second axis is composed by line D3 tangent to the terrestrial globe at point P and indicating the geographic North. It is obtained by the intersection between the plane defined by lines D1 and D2 and the plane perpendicular to line D2 and passing through P;

[0095] The third axis is line D4 tangent to the terrestrial globe and perpendicular to the said first and second axis.

[0096] The terrestrial frame is considered as invariant due to the fact that during the use of the sighting means, their moving are not enough important to create a significant variation of the direction of the vertical of the location.

[0097] Knowing the directions of the said first, second and third axes in the frame of reference formed by the trihedron,

the software program defines by a matrix inversion process, the position of the trihedron formed by the gyroscopes in the terrestrial frame of reference, thus the attitude of the sighting means and then defines the starting vectors of the integral which allows, during the moving of the sighting means, to determine the position vector of the latter as well as its elevation S and azimuth A.

[0098] According to a second mode of implementation of the invention, similar to the previous, the two axis inclinometer is replaced for example by a three axis accelerometer or by three accelerometers 17₁, 17₂, 17₃ arranged in a trihedron and as depicted in FIG. 3 attached to the sighting means, their position being accurately known with respect to the position of the gyrometers trihedron.

[0099] The software program of the processing means processes the signals emitted by the accelerometer(s) and determines, in known fashion, the direction of the vertical of location associated to point P.

[0100] As previously said, the software program determines by processing the signals derived from the gyroscopes and in known fashion, the direction of a line D1 parallel to the rotation axis of the earth, and besides the position of the terrestrial frame of reference in the frame formed by the gyroscopes trihedron, then the software determines by a matrix inversion process, the position of the trihedron formed by the gyroscopes in the terrestrial frame of reference and consequently the attitude of the sighting means, and finally the starting vector of the integral which allows, during the moving of the sighting means, to determine the position vector of the said means, and also its elevation S and its azimuth A.

[0101] According to another variant of embodiment of the invention in which the sensor is constituted by three accelerometers or by two inclinometers or by equivalent sensors, the resetting function is performed, whatever trajectory followed by the sighting means. For this reason, this type of resetting process is called dynamic algorithmic resetting.

[0102] As depicted in FIG. 3, the three gyrometers 14₁, 14₂, 14₃ permit the measurement of the rotation sustained by the sighting means 10 between two different instants in a Galilean frame of reference, for example in the frame constituted by the positioning of gyrometers 14₁, 14₂, 14₃. It should be noted that in this case where the sighting means stay at the same position (the same fixed point with respect to the earth) at each of the two instants, the gyrometers have measured the rotation of the earth.

[0103] The three accelerometers 17₁, 17₂, 17₃ make it possible to determine at any time the gravity force, which means the expression of the "gravity" vector, in the frame of reference associated to the sighting means 10. Moreover, the expression of this vector is known in a frame of reference to a point of the earth, this vector being vertical oriented backwards and this value being equal to 9.8 m/s⁻². The expressions of the gravity vector with respect to time in a terrestrial frame of reference are thus identical.

[0104] However the two expressions of the gravity vector of the same fixed point of the earth at two different instants in a same Galilean frame of reference are not identical, the two vectors forming an angle which is dependent on the elapsed time between the two instants, and more precisely on the rotation of the earth and on the latitude of the considered point.

[0105] The aim of this dynamic resetting is to identify the initial attitude of the sighting means **10**.

[0106] Using the maritime notation, the purpose is to determine the heading, roll and pitch coordinates of the sighting means at initialization time. This principle used utilizes the previous noticing.

[0107] Let P be a point on the surface of the earth.

[0108] Let $R_T(X_t, Y_t, Z_t)$ be the reference frame associated to point P. The X_t axis is the horizontal West to East axis oriented towards East, the Y_t axis being the horizontal South to North axis oriented towards North. The Z_t axis being the vertical axis oriented upwards.

[0109] Let $R_{MV}(X_s, Y_s, Z_s)$ be the reference frame connected to the sighting means **10** integrating the three gyrometers **14₁**, **14₂**, **14₃** and the three accelerometers **17₁**, **17₂**, **17₃**. At initialization time the direct trihedron (X_s, Y_s, Z_s) is defined in such a way that the successive rotations of:

[0110] a $-K$ angle (K : being the heading value) about the Z_t axis,

[0111] then of a $-T$ angle (T : being the pitch value) about the axis resulting from the previous rotation about the X_t axis,

[0112] then of a $-R$ angle (R : being the roll value) about the axis resulting from the 2 previous rotations, applied on the Y_t axis,

[0113] put the frame of reference R_T on the R_{MV} frame of reference. Let T_0 be this instant.

[0114] The K , T and R angle are not known. Their identification is the aim of the process implemented.

[0115] At different instants T_i the three accelerometers **17₁**, **17₂**, **17₃** make it possible to measure the expression of the "gravity" vector in the frame of reference $R_{MV}(T_i)$. The expression of this vector in the $R_T(T_i)$ frame of reference is known and equal to $(0, 0, -9.8)$.

[0116] The expression of this vector in the $R_{MV}(T_i)$ frame of reference is computed after completion of the following rotations:

[0117] the rotation of a $-\alpha$ angle, which is a function of the elapsed time between instants T_0 and T_i

$$\left(\frac{\alpha}{T_i - T_0} = 15^\circ/h\right)$$

[0118] about the pole axis oriented from the South to North, that is to say, around the axis of the earth rotation, and which is only a function in the $R_T(T_0)$ or $R_T(T_i)$ frame of reference of point P latitude where the sighting means (**10**) are,

[0119] the rotations of $-K$, $-T$, and $-R$ angles previously mentioned,

[0120] the rotation, which results from, the integration of the incremental angles measured by the gyrometers.

[0121] However this computation cannot be completely performed since the K , T and R values are not known.

Nevertheless an appropriate algorithm computes them in order to make identical the expressions of the "gravity" vector calculated and measured by the accelerometers at times $T_0, T_1, T_i \dots T_n$.

[0122] Knowing K , T and R the software program of the processing means **30** determines then, as previously said, the position of the trihedron formed by the gyroscopes in the terrestrial frame of reference, thus the attitude of the sighting means and defines then the starting vectors of the integral, which allows, during the moving of the sighting means, to determine the position vectors of the said means, and also its elevation S and azimuth A .

[0123] Otherwise the calculation of the gravity vector in the $R_{MV}(T_i)$ frame of reference needs to know the latitude. The latter can be either known or determined by a system such as the GPS, or computed by the means of the invention. In this latter case the software program shall also and previously said compute, as a complement of the three parameters K , T and R , the latitude through a slower convergence process.

[0124] The evolution in time of the "gravity" vector in a Galilean frame of reference is a consequence of the terrestrial rotation. This method comes down to the dynamic measurement of the earth's rotation.

[0125] No assumption is made on the attitude of the sighting means **10** at the successive times T_0 or T_i . This method doesn't take into account any resetting support or a rest position. It allows performing an algorithmic resetting, said dynamic resetting.

[0126] In this example of embodiment, the periodicity for the execution of the algorithmic resetting was some tens of seconds.

[0127] According to another variant of embodiment of the invention the resetting means have at least two magnetic receivers positioned in a non parallel and rigid arrangement on the sighting means, for example by use of a reinforced molding, have at least a low frequency and electromagnetic emitter whose position has been preliminarily defined in a given frame of reference, for example a frame of reference linked to this emitter.

[0128] In order to define the position of the sighting means with respect to three non parallel axes, it is necessary to have three magnetic receivers arranged along a trihedron and rigidly fastened to the sighting means, and either three non juxtaposed emitters, or three or more emitters, or an emitter which stimulates sequentially for example three coils positioned in a trihedron configuration.

[0129] The magnetic receivers, in this case coils, generate each one a signal representative of the intensity the direction and the way of the low frequency magnetic field that they receive. These signals are sent to the processing means, which process them and compute the position and the direction, that is to say the attitude of the sighting means, from data representing the expected cartography of the magnetic field which has preliminarily been loaded in these processing means.

[0130] These resetting means have a range of about ten meters and position accuracy within one millimeter and an angular accuracy within a tenth of a degree.

[0131] Knowing the position and the attitude of the sighting means in a predefined frame of reference, the resetting of the gyroscopes in this frame of reference or a frame of reference linked to it, can be performed.

[0132] It should be noted that some gyrometers are sensible to magnetic fields. In this case it is necessary to armour them by the embodiment of a sheet of metal placed around them and/or to compensate the drift induced by the magnetic field by a calibration and by a loading in the processing means of data representing the evolution of the drift with respect to the magnitude of the magnetic field and by a compensation at all times of the drift by the software.

[0133] According to another embodiment of the invention, the resetting means comprise at least a fixed camera rigidly fastened to the sighting means. This camera generates a signal representative of the observed image. This signal is processed by known image processing means capable of determining the position of a pattern inside the said image. This pattern may be constituted by a star, such as the moon the sun or a real star, or by a landscape or by particular patterns that have been arranged in places the coordinates of which have been defined in a predefined frame of reference. Every time that the sought pattern is found, its coordinates or its attitude are sent to processing means, and the software program performs a resetting of the gyrometers in order to align the signals of position provided by the gyrometers with the real position of the sighting means.

[0134] When a star constitutes the pattern, it is necessary to load in the memory of the processing means a complete cartography of the stars and planets according to the time and to have an accurate time reference.

[0135] The camera can be mobile and when a pattern is detected, tracking software of the said pattern is capable of generating the moving of the camera in order to keep the pattern on the center of the image.

[0136] According to another variant of embodiment of the invention, the resetting means comprise at least two accelerometers and preferably three, rigidly fastened to the sighting means, for example by means of a reinforced molding et according to a trihedron.

[0137] These accelerometers emit each one a signal representative of the acceleration of the sighting means, which is transmitted to the processing means of the signals derived from the gyroscopes.

[0138] For the resetting execution, it is necessary to know the position of a point, for example of the landscape, then in a first stage to aim this point with the sighting means and to move the sighting means, preferably of some meters, and in second stage to aim again the said point.

[0139] The processing means of the signals derived from the gyrometers being capable of determining the elevation S and the azimuth A of the said point in an absolute frame of reference, the position of this point is then defined by a triangulation procedure using the accelerations created by the two sightings and the values of the elevation S and of the azimuth A. Knowing the precise position of the said point and the position calculated from the triangulation, the resetting of the gyroscopes is next carried out by a comparison of the calculated position with the real position of the point.

[0140] Moreover, the combined use of accelerometers with gyroscopes allows performing two complementary functions. The first relates to the computation of the parallax and the second the passive telemetry. To perform the latter it is enough to aim the same target from two different positions, then, knowing the elevation S and the azimuth A of this target, taking into account the signals derived from the gyroscopes and the distance between these positions determined continuously from the signals of the accelerometers, the distance and the attitude of this target are defined by means of a triangulation.

[0141] In all the variants of embodiment described above, the sighting means and the processing means can be portable, their weight being inferior to 5 kg so as to allow an easy utilization.

[0142] The computation of the attitude can be decomposed as follows:

[0143] In all the above variants of embodiment, the moving of the sighting means **10** activates the integration of the three incremental angles for each of the three axes related to this means.

[0144] The attitude of the device is thus known at any time.

[0145] However the expression of the sighting means attitude shall be in accordance with the requirements of the external means **60**.

[0146] In this embodiment, achieving this conformity requires two steps.

[0147] The first consists in calculating the attitude of the sighting means in a geographic frame of reference with respect to an electromagnetic emitter or with respect to a pattern whose position doesn't change or changes a very little.

[0148] The second consists in expressing the attitude in the operating frame of reference, in this case the frame of reference of the weapon system.

[0149] This frame of reference can be located several tens of meters from the resetting support, and for that reason the parallax error may be non-negligible, especially if the objects being sighted are close; such objects can be swimmers or small boats.

[0150] Once the operational need is known, the sighting field is separated into two domains. One is the domain of positive (or slightly negative) elevations, which cannot be floating targets. For these objects a default distance of approximately 4 000 meters is used to correct the parallax. The other domain is that of negative elevations, which are assumed to be floating targets. If the altitude of the device is above the sea level is known, and if the sighting elevation (measured by the device) is known, a simple trigonometric calculation can be used to estimate the distance of the object, and it is that distance which is used as the basis for calculating parallaxes.

[0151] In addition, the movements of the sight due to operator tremors, in an environment, which is both stressful and perturbed by movements of the ship, generate noise in the sighting data, which can make it difficult and even impossible to process.

[0152] To eliminate this drawback, a data filtration program is built in so as to stabilize the output signal. This filtration can be of the low-pass type or a KALMANN filter, in order to take into account target maneuvers in a given envelope without trailing.

[0153] Since the movement can be fairly fast, and the incremental angles measured by the measurement system fairly large, a suitable model can return conditions to the previous state.

[0154] The sighting means can incorporate a device for acquisition of an image, in this case the latter is used to allow by means of an image stabilization process which filters the parasitical movements, so as to allow the identification of the target or the calculation of the accurate position of the target with respect to the operator's sight, by use of an image processing.

[0155] A continuous process defines the attitude of the sighting instrument. Before any target designation and in order to operate the algorithmic resetting function, the sighting member is in known position at rest.

[0156] The software operated by the processing means 30 is aimed to process the rough data provided by the sighting instrument, device that allows the operator of the means according to the invention, to determine the elevation and the azimuth of a target while aiming it.

[0157] The software program carries out the following functions:

[0158] Target designation function, which causes data to be acquired from the sighting instrument and processes them to obtain the desired elevation and azimuth,

[0159] Transmission function, which sends the azimuth and elevation data for display on the imaging means and/or for the purpose of a XX weapon system,

[0160] Absolute position function, which allows correction at regular intervals of the sighting instrument's drift due to the use of gyrometers,

[0161] Imaging function, which displays the operational state of the elements according to the invention.

[0162] The target designation function takes place continuously when the sighting instrument is in operational mode, i.e. outside the resetting support. The time required to process the gyroscopic data must be minimal, for example on the order of a few milliseconds, to allow processing of much data as possible coming from the gyrometers, and thus to allow better tracking of the change in the angular increments and the angles deduced there from so as to limit errors during processing. Depending on the size of the angular increments derived from the gyrometer, a model is established to gain as much independence as possible from the commutativity limits of rotations in space.

[0163] The input data required for this function are:

[0164] The angular increments derived from the gyrometers: $dqx(t)$, $dqy(t)$, $dqz(t)$,

[0165] u , v , w which are position vectors of the sighting instrument at time $t-dt$ in the absolute frame of reference of the resetting support at T_0 (time of the last resetting).

[0166] The output data are:

[0167] u , v , w which are position vectors of the sighting instrument at time t in the absolute frame of reference of the resetting support at T_0 ,

[0168] elevation S and azimuth A in the absolute frame of reference at time t .

[0169] Integration of the gyroscopic data is accomplished in the absolute frame of reference of the resetting support at time T_0 . At the time of sighting, when the trigger is pressed, taking into account the rotation of the earth that has additionally been measured by the gyrometers since processing began terminates processing. This is done by operating in the absolute frame of reference of the resetting support at t , the time of sighting, then subtracting the absolute elevation and azimuth of the sighting instrument with respect to the ship.

[0170] Correction of the gyrometric data is performed as follows:

[0171] The three gyrometers supply: $Sdqx(t)$, $Sdq(t)$, $Sdqz(t)$.

[0172] It is easy to calculate $dqy(t)$, and $dqz(t)$:

$$dqx(t) = Sdqx(t) - Sdqx(t-dt)$$

[0173] The same applies to $dqy(t)$, and $dqz(t)$.

[0174] After the multiple automatic calibrations performed in known fashion at this level, such as compensation for gyrometer drift as a function of time, temperature, magnetic field, noise filtration, etc., the data called— $dqv(t)$, $dqv(t)$, $dqw(t)$ —are integrated according to the method described above.

[0175] The transmission function is very simple, since it consists in sending calculated values for elevation and azimuth in the absolute frame of reference of the vessel at time t , to a memory and to the weapon system and/or for display on the imaging means for display.

[0176] This function is activated by moving switch 16 from the open position to the closed position. It is accompanied by the emission of an audible signal and/or a light signal, and display of a positive datum on the imaging means.

[0177] As long as the software detects the stable rest status of the sighting member, an automatic algorithmic resetting takes place periodically and the gyrometer drifts are analyzed in terms of both time and temperature. If the software detects a moving during processing, the resetting that is in progress is cancelled, and the values from the previous algorithmic resetting are used.

[0178] The input values are:

[0179] position of switch 16,

[0180] values derived from external means 50,

[0181] the position of the sighting instrument (U_0 , V_0 , W_0) in the relative frame of reference of the ship when the sighting instrument is in the terrestrial or geographic frame of reference with respect to an electromagnetic emitter or to a pattern whose position doesn't change or change a very little,

- [0182] the values for heading K, roll Rr, and pitch Ta of the ship acquired during the last operation of the algorithmic resetting function.
- [0183] The output values are:
- [0184] To, uo, vo, wo,
- [0185] The position vectors of the sighting instrument at To,
- [0186] Du.
- [0187] The data processing is performed as follows:
- [0188] The values for heading K, roll Rr, and pitch Ta of the ship are acquired.
- [0189] At initialization of the program, the sighting means 10 are at rest and the software of the processing means 30 operates the sub-routine related to the algorithmic resetting of the gyrometers. The input parameters used are the position of the resetting support with respect to the ship. This makes it possible to determine the position of the sighting instrument 10 when it is at rest, in the terrestrial or geographic frame of reference, with respect to an electromagnetic emitter or a pattern whose position doesn't change or change a very little
- [0190] The system status imaging function makes it possible to display the status of certain functions:
- [0191] Transmissions from the gyrometers to the computer,
- [0192] Transmission of values derived from the external means,
- [0193] Transmission from the trigger to the computer,
- [0194] Transmission from the resetting sensor to the computer,
- [0195] as well as certain values such as the calculated elevation and azimuth, the heading, roll, pitch, and latitude values, as well as the time, the time of last resetting, the most recent length of time in use since resetting, the observed drift, etc. Moreover in case of use of an electronic imaging sensor, the video signal can be recorded, continuously or only when switch 16 is triggered, and be displayed on a monitor, simultaneously with certain information such as the direction of the aimed target, its range, or its type when a recognition and/or identification known function is applied to the video signal by the processing means.
- [0196] To test the reception of data from the gyrometers, it is necessary to verify that the gyroscopic data are in fact arriving at the processing unit every Dt. If no data has arrived at the processing unit after 3 Dt, a fault is detected, and the "transmission from gyrometers" variable switches from 1 to 0.
- [0197] The same principle is used to test the transmission of values from the external means.
- [0198] When the trigger is pulled, switch 16 closes and the "trigger variable" switches from 0 to 1 on the screen.
- [0199] In the same fashion, when the algorithmic resetting function is activated, the "resetting variable" switches from 0 to 1 on the screen.

- [0200] The means according to the invention are utilized by an operator. The sighting means 10 are at rest, for example laid down or hanged on any plane. When the operator sees a target, he removes the sighting means 10, and then points them by use of the sighting member 13 in the direction of the target, and presses switch 16 when he considers that they are correctly positioned with respect to the target. Means 30 then calculates the elevation and azimuth of the target and transmit those values to the weapon system, which causes orientation of the weapon as a function of those values and changes in the attitude of the ship since said transmission of values, those changes being determined, as mentioned above, by means 50.
- [0201] Immediately after the transmission, the gunner can sight on another target and press switch 16. Means 30 then calculate the elevation and the azimuth of the new target, and transmit those values to the weapon system which stores said values in memory and can orient the weapon toward that new target immediately after firing toward the first target.
- [0202] The gunner can thus sight on several targets in succession in a minimal time without being obliged to wait for the end of the weapon firing sequence, which optimizes the total time required for such firings and thus decreases the vulnerability of the ship.
- [0203] It also gives to the gunner the ability to re-sight on a target if the weapon's projectile did not hit it, even if the weapon system is oriented toward another target.
- [0204] In addition, after acquiring the target or the various targets, the gunner can perform complementary tasks or can move without having the weapon system react to his movements.
- [0205] Acquisition of the gyrometers is performed at aiming interval Dt of between 5 ms and 100 ms. These values are integrated, it is known to model in numerical data that integration so as to obtain accurate results, for example by use of prediction-correction models such as the models of Adams-Boulton-Bashford, Runge-Kulta or Burlirsch-Stoer. However, with portable calculating means, it is not possible to perform more complex calculations in real time. One of the purposes of the invention is to solve this problem by proposing an integration method consisting in performing successively, on the basis of the gyroscopic values obtained between time t0 and time t1, first calculations using a complex model which cannot operate in real time but does give accurate results; then, based on the gyroscopic values obtained between time t1 and time 2, second calculations using a simplified model capable of being utilized in real time.
- [0206] The advantage of this succession of steps is that it can yield elevation and azimuth calculations in real time with respect to the closure of switch 16 and, with that objective in mind, gives more accurate results than the use of only the complex model or the simplified model.
- [0207] It is obvious that for ergonomic purposes, numerous modifications can be made to the embodiment presented. For example the pistol shape aspect of the sighting means can be replaced by a rifle aspect (with or without pedestal), etc.
- [0208] In addition, the sighting means can be applied to helmets such as the one described in U.S. Pat. No. 4,722,60,

to a headband, or to binoculars, and the software program can have a self-adapting algorithm for calculating the drift of the gyroscopes.

[0209] In addition, other means can be utilized with those of the invention. Thus, a GPS system or the equivalent can be associated to the processing means so as to corroborate the position information calculated from the signals derived from the gyroscopes. On the other hand a laser rangefinder can be used to determine the distance of a target or to corroborate the position calculations performed by processing the signals coming from the accelerometers or the gyroscopes.

[0210] In addition, the different measurements made (speed of the rotation of the earth, magnitude of the terrestrial gravity field, magnitude of the terrestrial magnetic field, etc) can be advantageously utilized to verify the rest status of the sighting member and also to perform correlations, calibrations and error checks.

1. A device capable of determining the direction of a target in a predefined frame of reference and of the type having sighting means (10), means having a sighting member (13), three gyroscopes (14₁, 14₂, 14₃) arranged along three axes in different planes, means for control (16), means (20) for resetting said sighting means (10) and means (30) for processing signals derived from the sighting means (10), said processing means (30) being capable of determining the direction between the sighting means (10) and the target and of transmitting to imaging means (40) or to external means (50, 60) and also means (16) for controlling the transmission to the imaging means (40) or to external means (50, 60), of representative values of the direction between the sighting means (10) and the target, this device being characterized in that it comprises at least one non gyroscopic sensor (17) arranged on the sighting means (10) and capable to emit a signal for its transmission to the said processing means (30), and in that the processing means are capable of determining a terrestrial frame of reference from the signals derived from the said gyroscopes (14₁, 14₂, 14₃) and from the said non gyroscopic sensor (17).

2. The device as defined in claim 1, wherein the sighting means (30) are capable of determining on the one hand, the direction of a line D1 parallel to the earth's rotation axis and going through point P where the sighting means are, by processing the signals derived from the gyroscopes, and on the other hand, the direction of the vertical D2 of the location associated to point P, by processing the signals derived from the said non gyroscopic sensor.

3. The device as defined in any one of claim 1 or 2, wherein the axes of the terrestrial frame are the vertical of the location, geographical north, geographic east or geographic west.

4. The device as defined in any one of claims 1 through 3, wherein the said at least one non-gyroscopic sensor (17) is composed of one two axes inclinometer or at least two inclinometers.

5. The device as defined in any one of claims 1 through 3, wherein the said "at least one sensor" has one multi-axes accelerometer or at least two accelerometers.

6. The device as defined in any one of claims 1 through 3, wherein the said "at least one sensor" has one electronic imaging sensor.

7. The device as defined in claim 6, wherein the one electronic imaging sensor is capable of generating a repre-

sentative imaging signal, and which is transmitted to processing means of this signal capable of determining the position of a pattern in the said image.

8. The device as defined in claim 7, wherein the processing means associated to the imaging electronic sensor allow compensating the operator tremors.

9. The device as defined in any one of claims 7 through 8, wherein the processing means of the sighting means are capable of compensating the operator tremors, with the value of the optical field of the electronic imaging sensor.

10. The device as defined in any one of claims 8 through 9, wherein the processing means of the sighting means, are capable of determining the angular field of the electronic imaging sensor from the relationship between the operator tremors derived from the signal of the electronic sensor, and the signal of the sighting means.

11. The device as defined in any one of claims 6 through 10, wherein the processing means of the sighting means are capable of generating, from the signals of the electronic image sensor, and the sighting means, a signed image.

12. The device as defined in claim 11, wherein the processing means of the sighting means are capable of reconstituting the global landscape from the signed images, with position information for different zones of the latter.

13. The device as defined in any one of claims 11 through 12, wherein it is constituted by display means of the said signed images and/or of the rebuilt the landscape.

14. The device as defined in any one of claims 1 through 13, wherein the processing means are capable of participating to the transmission of identification elements of the target, and/or to the detection of the absolute direction of the sighting means.

15. The device as defined in any one of claims 1 through 14, wherein it is constituted by recording means of the signal coming from the electronic imaging sensor, and/or it comprises display means of the said images and also of some information such as the direction of the aimed target, its range and/or its nature.

16. The device as defined in any one of claims 1 through 3, wherein the said at least one sensor utilizes at least two electromagnetic receivers.

17. The device as defined in claims 16, wherein it comprises an electromagnetic emitter.

18. The device as defined in any one of claims 1 through 17, wherein it has three optical gyroscopes, for example fiber-optic gyroscopes.

19. The device as defined in any one of claims 1 through 18, wherein the processing means have a power supply and calculating and management means using a software program that performs several functions.

20. The device as defined in claim 19, wherein the software program performs three main functions:

Target designation function, which causes data to be acquired from the sighting instrument and processes them to obtain the desired elevation and azimuth;

Transmission function, which sends the azimuth and elevation data for display on the imaging means and/or for the purpose of a weapon system;

Absolute position function, which allows correction at regular intervals of the sighting instrument's drift due to the use of gyroscopes.

21. The device as defined in claim 20, wherein the software program also performs a display function of the operational status of the invention.

22. The device as defined in any one of claims 1 through 3, wherein the said positioning radio means, such as satellite means of GPS type, constitutes at least one sensor.

23. The device as defined in any one of claims 1 through 22, wherein the sighting means comprise the acquisition of the geographic position by radio means, such as satellite means of GPS type.

24. The device as defined in any one of claims 1 through 23, wherein the sighting means have a rangefinder.

25. The device as defined in any one of claims 1 through 24, wherein the processing means comprise triangulation means, capable of performing a discreet telemetry.

26. The resetting process of the device capable of determining the direction of a target in a predefined frame of reference and of the type having sighting means (10), means having a sighting member (13), three gyrometers (14₁, 14₂, 14₃) arranged along three axes in different planes, and having at least one non gyroscopic sensor (17), these elements being capable of emitting a signal for its transmission to the said processing means (30), the processing means (30) being capable of determining the direction between the sighting means (10) and the target, is characterized in that it comprises a stage consisting in determining a terrestrial frame of reference from the signals derived from the said gyrometers (14₁, 14₂, 14₃) and from the said non gyroscopic sensor (17).

27. A process as defined in claim 26, which includes a step that determines, on the one hand the direction of a line D1 parallel to the earth's rotation axis and going through point P where the sighting means (10) are, by processing the signals derived from the gyroscopes, and on the other hand, the direction of the vertical D2 of the location associated to point P, by processing the two signals derived from the said sensor.

28. A process as defined in claim 27, which includes an additional step that determines the geographic north direction, this direction being obtained by the intersection of the plane defined by the D1 and D2 lines with the plane perpendicular to D2 and coming through P.

29. A process as defined in claim 26, which utilizes on the one hand sighting means comprising at least three sensors, that is to say, three electromagnetic receivers, and on the other hand the device comprises an electromagnetic emitter, the process being characterized in that the processing means (30) compute the position and the orientation, that is to say the attitude of the sighting means (10) by processing the signals derived from the magnetic sensors and of the cartography of the magnetic field expected, which has been loaded before in the memory of the these processing means.

30. A process as defined in claim 30, which utilizes sighting means composed of an electronic imaging sensor, such as a camera rigidly fastened to the sighting means, this camera generating a signal representative of the image observed, the process being characterized in that it uses a step that makes the imaging process capable of determining the position of a pattern in the said image, the position of this pattern being known.

31. A process as defined in claim 30, wherein the said second frame of reference is a geographic frame of reference with respect to a pattern whose position doesn't change or changes very little.

32. A process as defined in any one of claims 26 through 31, wherein it includes a stage of calculation of K, T and R angles by the processing means, defined as follows: Knowing that:

P is the point of the earth surface where the sighting means are;

R_T (X_t, Y_t, Z_t) is a reference frame associated to point P and connected to the earth, X_t axis being the horizontal West to East axis oriented towards East, Y_t axis being the horizontal South to North axis oriented towards North, and Z_t axis being the vertical axis oriented upwards.

R_{MV} (X_s, Y_s, Z_s) is a frame of reference connected to the sighting means (10) integrating the three gyrometers (14₁, 14₂, 14₃) and the said at least one non gyroscopic sensor,

the successive rotations of a -K angle about Z_t axis, then of a -T angle about the axis resulting from the previous rotation applied on X_t axis, then of a -R angle about the axis resulting from the two previous rotations, applied on Y_t axis,

put the frame of reference R_T on the R_{MV} frame of reference.

33. A process as defined in any one of claims 26 through 32, wherein the processing means (30) include a step by which they determine the value of the gravity vector either in a continuous process or in a step by step one carrying out process at T₀, T₁, T_i, T_n, of the signals sent by the gyroscopes or the said at least one non gyroscopic sensor (17) arranged on the sighting means (10).

34. A process as defined in claim 33, wherein it computes in a first step the expression of the R_T(T_i) frame of reference into the R_{MV}(T_i) frame of reference, through the implementation of the following rotations:

the rotation of a -α angle, which is a function of the elapsed time between instants T₀ and T_i

$$\left(\frac{\alpha}{T_i - T_0} = 15^\circ/h\right)$$

about the pole axis oriented from the South to North, that is to say, around the rotation axis of the earth, and which is only a function of point P latitude where the sighting means (10) are, in the frame of reference R_T(T₀) or R_T(T_i);

the rotations of -K, -T, and -R angles previously mentioned;

the rotation which results from the integration of the incremental angles measured by the gyrometers;

and wherein, in a second stage, it determines K, T, and R angles, either by an inversion process of the equalization made of the computed and of the measured values of the gravity vector, or by a minimization process of

the error function, by use of an algorithm aimed to seek the minimum value of a function of many parameters calculated on a sample of data, for example, by use of an algorithm of simple down hill type or of simulated annealing type, or by use of any one of dedicated algorithms, such as quadratic programming of Kar-makar, More and Toraldo.

35. A process as defined in any one of claims **31** through **34**, wherein it comprises a step for determination of the latitude of the place where the sighting means are.

36. A process as defined in claim 32, wherein the said second step consists in computing latitude L as a comple-ment of K, T and R angles. **35/36**

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