

The present invention relates to determining an orientation tied to a mobile system, for example to a helmet sight, and the subject of the invention is more particularly a method, and the corresponding device, for
5 determining an orientation related to a mobile system enabling great accuracy to be obtained.

The problem consists in accurately identifying the direction of an oriented axis without having material contact with it, in particular in helmet sight systems
10 used in combat aircraft or helicopters. The operation of such a system is briefly recalled hereinbelow: by means of an attached collimator, the pilot sees, through a semi-reflecting mirror integral with the helmet and interposed on a viewing axis, the image of a reticule
15 projected to infinity in superposition with the scene outside. When he wishes to designate a target, the pilot brings this reticule into coincidence with the target and signals that the coincidence is achieved by means, for example, of a push-button control provided for this
20 purpose.

On condition of identifying, at the moment of signalling, the exact position of the helmet, it is possible to determine the sight direction with respect to the aircraft and to designate the target to a weapon
25 system or to point an optical or other system in this direction.

An orientation measurement device, especially for a helmet sight system is known, especially from the French Patent No. 79/14441, in which, in order to bring
30 the line of sight determined by the position of the pilot's helmet back into a reference frame tied to the aircraft, a position sensor consisting of three orthogonal electromagnetic coils is placed on the helmet; moreover, at a fixed point in the cockpit, three other
35 electromagnetic coils are placed forming a transmitter or "radiator" according to the terminology used in the field. The method then consists in passing an electrical current, in succession, in each coil of the transmitter (forming the fixed trihedron). These currents cause the

appearance, in succession, of three magnetic fields associated with them which are picked up by the coils of the sensor (forming the mobile trihedron tied to the helmet).

5 For each magnetic field emitted, the three corresponding orthogonal components are picked up in the coils of the sensor. The nine resulting components then enable the transformation (rotation) to be found making it possible to pass from the mobile trihedron to the
10 fixed trihedron. In fact, these nine components depend:

- on the position of the sensor in space;
- on the orientation of the sensor.

 In fact, the transformation resulting from such a method may be quite different from the transformation
15 of the coordinates making it possible to pass effectively from the mobile reference trihedron to the reference trihedron fixed with respect to the aircraft, especially because magnetic fields are used. The reason for this is that these fields may be appreciably disrupted because of
20 all the metallic elements of the environment, which create reflections of magnetic waves in the cockpit. This drawback is mentioned, for example in the system described in the US Patent 4,287,809, which is designed to solve it by carrying out prior measurements. In
25 addition, drawbacks inherent in the construction of the magnetic transmitting or receiving coils also create disruptions.

 The determination of a direction using the laws of electromagnetism in free space is therefore not
30 possible when the space in question is the cockpit of an aircraft. This is why certain known devices provide, before each measurement, the storing in memory of prior measurements and the comparison of measurements carried out at a given instant with the measurements stored in
35 memory so as to determine the rotation which makes the fixed trihedron pass to the mobile trihedron. Such a method requires the storing in memory of a very large quantity of measurements which have to be integrally re-entered as soon as parameters such as, for example, the

exact position of the mobile transmitter with respect to the line of sight, change.

5 The subject of the invention is a method according to Claim 1, and the device according to Claim 14, for determining an orientation in a mobile system making it possible to use, in operation, the same measurement method as previously, but avoiding the abovementioned drawbacks.

10 In order to do this, in a prior phase, modelling, taking into account the disruptions, especially magnetic disruptions, in the cockpit in which the detection system is placed, is set up on the basis of known particular orientations of the mobile sensor or on the basis of known particular orientations of the line of sight and
15 for each orientation on the basis of a set of positions of m , the origin of the reference frame constituted by the mobile sensor. This phase makes it possible to approach, from actual measurements, the complex relationships between position and orientation which are due to
20 the reflections of the magnetic fields and to the physical limits of the transmitter and of the sensor and leads to the prior determination of an overall modelling function taking into account disruptive effects. This prior phase, possibly completed by an initialization,
25 then makes it possible, in operation, to determine directly the orientation associated with any position of the mobile system from the actual experimental measurements.

30 According to the invention, a method for determining an orientation tied to a system which is mobile in a defined space, using a magnetic position and orientation detection system which includes a transmitter formed by three orthogonal coils having a fixed position in the defined space and a sensor, formed by three
35 orthogonal coils, which is attached to the mobile system, r being the distance between the origin of the transmitter reference frame and the origin of the sensor reference frame, a detection cycle consisting in transmitting in succession in the three coils of the

transmitter and in measuring the field components generated in the coils of the receiver, is characterized in that a prior phase of modelling the defined space consists in carrying out measurements of the magnetic fields in the sensor for a set of known positions of the mobile system with respect to a reference frame called cartographic reference frame, modelling parameters deduced from the reference measurements at each point being calculated in order to deduce therefrom the relative rotation of the sensor in the cartographic reference frame of the reference measurements, and in that, during use, the current orientation of the mobile system is determined directly from the modelling parameters constituting a compact position modelling function of the disruptive effects, which is a function of the position.

The subject of the invention is also the device intended for implementing this method.

The invention will be better understood and other characteristics will appear with the aid of the description which follows, with reference to the appended figures.

- Figure 1 is a block diagram of the device according to the invention.

- Figure 2 illustrates the various steps of the method according to the invention.

Figure 1 depicts diagrammatically a transmitter 1 which includes three coils arranged in a trirectangular trihedron; this transmitter is placed at a fixed point in a given space and, in the example described, this space is the cockpit of an aircraft; a central processing unit 10, which forms part of a set of onboard electronic equipment, delivers an electrical excitation signal in succession to the three coils of the transmitter 1, during successive cycles, via an amplifier device 20 under control from a control panel 30.

A sensor 2, arranged in flight phase on the helmet of the pilot of the aircraft and also formed by three coils arranged in a trirectangular trihedron, is also connected to the central processing unit 10 via a

connection module 40; this sensor may change position in the given space, in the flight phase according to the pilot's head movements and in the prior phase via a robot, in order to occupy predetermined positions. The central processing unit 10 includes a measuring element which receives from the sensor 2, during each measurement cycle, nine signals, as 3 times 3 signals, which are the signals induced, by successive energizations of each of the coils of the transmitter 1, in each of the coils of the sensor 2. The amplitudes of these nine signals constitute the nine values of a square matrix of dimension 3×3 . The problem is then to determine, with the aid of the laws of electromagnetism, the transformation, i.e. the rotation, which makes it possible to pass from the mobile reference frame formed by the sensor 2 to the aircraft reference frame.

By convention, the origin of the reference frame formed by the transmitter 1 is the point 0, the distance O_m from the transmitter 1 to the sensor 2 is called r , with $\vec{O_m/m} = \vec{u}$ where $\vec{u}$ is the unit vector in the direction O_m with x, y, z as projections in the fixed trihedron.

If a first measurement is carried out at the point m , the origin of the reference frame formed by the sensor, a nine-component matrix P is obtained; if a second measurement is carried out, with a different orientation of the sensor and the same origin m , a second matrix M of nine components is obtained; the matrix M may be written as:

$$M = R.P$$

where R is a matrix which corresponds to a pure rotation, such that:

$${}^tR = R^{-1}$$

this expressing that the transpose tR of a rotation matrix is equal to its inverse, R^{-1} ; therefore the product of the transpose tM of M by M is written as:

$${}^tMM = {}^tP.{}^tR.R.P = {}^tP.R^{-1}.R.P = {}^tP.P.$$

The product of a measurement matrix transposed by the matrix itself is therefore, in principle, invariant

at a given point m , irrespective of the rotation of the reference frame; in addition, the product matrix is symmetrical.

5 Theoretically, P and $M.M$ may be expressed as a function of r, x, y, z with the aid of the Maxwell equations characterizing the laws of electromagnetic propagation; in reality, this is not possible since the transmitter and the sensor are not perfect dipoles, because the space in the cockpit is not free space, and
10 because the helmet carries disruptive masses which are mobile at the same time as it.

As indicated hereinabove, in order to solve this problem, the method according to the invention consists in setting up a prior model on the basis of actual
15 measurements carried out for known predetermined positions and orientations of the sensor (or of a line of sight which is tied to it).

In order to do this, in a prior phase, the central processing unit initiates systematic measurements
20 carried out, in a first step, by always keeping the same orientation at a sensor, 2, and this is done in a mesh constituted by a set of points m in the cockpit where the sensor 2 may be located when it is placed on the helmet of the pilot in his flying position. A set of measurement
25 matrices of dimensions 3 by 3 associated with the set of points m is therefore obtained. These matrices are transmitted, via an interface circuit 50, to the memory of a computer 60 called modelling computer, at another time in order to be stored and processed therein. These
30 measurements may be carried out with the receiver alone, then called magnetic cartography sensor, moved by a robot, that is to say without the helmet and the pilot. These measurements therefore make it possible to set up
35 a magnetic "cartography" of the volume in which the sensor 2 may be located, for a particular orientation of this sensor. Preferably, this mapping is carried out according to a regular mesh in the three axes, with a spacing of from 3 to 4 cm.

Subsequently other measurements are carried out,

always with the cartography sensor alone, but with other mechanically known orientations of this sensor at several uniformly spaced points.

If P is identified with the measurement matrix
5 obtained when the axes of the coils of the sensor coincide with the reference frame of the cartography, that is to say the fixed reference frame of the robot tied directly to the aircraft reference frame, an overall function connecting the components of P to the components
10 of tMM is sought from the measurement matrices corresponding to the first orientation. This function is therefore a representation of the disruptive effects tied to the movement of the sensor in the cockpit, the sensor being kept in a fixed orientation. In order to do this,
15 in one embodiment, this step of the method consists in seeking 9 optimum polynomial relationships linking each component of the nine-component matrix P to the 6 components of the symmetrical matrix tMM . The coefficients of the monomials forming the 9 polynomials constitute the
20 function F_p sought. The solution is facilitated by the following homogenization:

$r^4P = F_p(r^7 \cdot {}^tMM)$, where $r = Om$. In fact, since the magnetic fields decrease as $1/r^3$, a matrix product of the type tMM decreases as $1/r^6$; in order to seek a function
25 connecting P to tMM , it is advantageous to make the two entities to be connected dimensionally homogeneous, and to find a favourable common dimension for them. The most favourable dimension is the distance r.

The best approximation of r is given by the value
30 of the 6th root of the trace of the matrix tMM , resulting from the calculation under dipolar conditions.

After homogenization, as indicated hereinabove, each component of the matrix r^4P is identified with a polynomial which is a function of the terms of the matrix
35 $r^7 {}^tMM$, by linear regression over the 6 terms of $r^7 {}^tM.M$, taking as regressors e_k all the products of degree at most equal to 3 which are calculated at a point m from the measurement matrix M at this point. The products of degree 1 are the six terms $r^7 {}^tMM$, the products of degree

2 are all the products of two terms of tMM , including the square terms, etc. Up to the order 3, for the 6 terms of $r^7 {}^tMM$ resulting from a measurement matrix M at the point m , there are $k = 84$ regressors e_k . If n measurements each giving a matrix M have been set up at n points m , each component of $r^4(P)$, P_j ($j = 1$ to 9), is identified with n polynomials each being a function of a different set of regressors $(E)_i = (e_1, e_2, \dots, e_k)_i$, $i = 1$ to n which are calculated from the components of $r^7 {}^tMM$, and of the coefficients $(a_0, a_1, \dots, a_k)_j$ sought for this component:
 $P_j = a_0 + a_1 e_1 + \dots + a_k e_k$.

The coefficients are obtained by solving, in the least-squares sense according to the method called GRAM SCHMIDT method, the 9 independent systems, $P = E.A$, where E is the line matrix defined by the k regressors calculated for each point m of the cartography (E has k columns and n rows). A is the column matrix formed by the coefficients $(a_0 \dots a_k)_j$ from $j = 1$ to 9 sought, and P is the column matrix consisting of the measured value of this component P_j repeated n times.

The direct use of the 9 sets of coefficients $(a_0 \dots a_k)_1 \dots (a_0 \dots a_k)_9$ leads to a first approximation Mc of the cartography matrix P and therefore of the three angles G_1 (bearing), S_1 (elevation) and R_1 (roll) characteristic of the rotation of the sensor with respect to the reference frame of the cartography, through the relationship $M = R.Mc$.

Then, in a following step, from the measurements carried out at several points in various orientations of the sensor, an overall function F_r is sought such that $(G_2, S_2, R_2) = F_r(G_1, S_1, R_1, {}^tMM)$, (G_2, S_2, R_2) being true angles. This overall function is a representation of the disruptive effects induced by the rotation of the sensor.

This step therefore consists in seeking 3 optimum polynomial relationships between, on the one hand, each true angle (G_2, S_2, R_2) and, on the other hand, the three previously calculated corresponding approximate angles (G_1, S_1, R_1) resulting from the measurement and the various positions, in rotation, of the sensor reference

frame, that is to say the 6 components of $r^T {}^tM.M$.

The method used is similar to the one used for seeking F_p , that is to say that linear regression is carried out over the 6 terms of $r^T {}^tMM$ and the 3 terms G_1 , S_1 , R_1 , taking as regressors all the products of degree at least equal to 3, that is to say a constant and the product of degree 1, G_1 , S_1 , R_1 and the 6 terms of tMM , the products of degree 2 which are the previous ones squared and the cross terms of the type G_1S_1 , G_1R_1 , etc.
... $(G_1) ({}^tMM)_{ij}$... $(R_1) ({}^tMM)_{ij}$ etc.

Since the degree is limited to 3, this results in calculating 220 regressors.

The direct use of the 3 sets of coefficients a_i forming the modelling parameters arising from this modelling algorithm thus makes it possible to obtain, with very great accuracy, the orientation of the sensor in the reference frame of the cartography, and this is achieved using the angles G_1 , S_1 , R_1 approximated in a previous phase.

Once the cartography operations described hereinabove have been carried out in the wearer's cockpit, and after the cartography measurements have been stored in memory in the modelling computer assembly 60 at another time, the modelling parameters arising from the modelling algorithms described hereinabove are stored in memory in the onboard central processing unit 10. Next, measurements are carried out after the helmet has been adjusted (adjustment of the optical system, adjustment of its attachment to the pilot's head, etc.).

If M is then a measurement matrix corresponding to the magnetic field components detected, in the reference frame formed by the sensor fixed to the helmet, during successive transmission from the three coils of the fixed transmitter for one position of the helmet and therefore of the mobile reference frame, the product ${}^tM.M$ is calculated and the measurement of the angles of the sensor in the cartography reference frame, M_c , may thus be calculated directly:

The rotation R of the helmet-tied sensor with

respect to the cartography sensor is then determined by:

$$R = McM^{-1}.$$

Since the position of the sensor is then accurately fixed, it is possible rapidly to carry out, if the
5 matrix I for rotation of the line of sight with respect to the sensor is known, the transformation making it possible to pass from the sensor reference frame to the cartographic reference frame tied to the aircraft reference frame, especially in order to give a firing system
10 the firing direction determined from the helmet sight.

The equation of the line of sight L_v in the reference system tied to the wearer is then obtained in the following manner: $L_v = RI^{-1}$ where $R = McM^{-1}$, that is $L_v = McM^{-1}I^{-1}$.

15 But, as a general rule, a step of initialization of the line of sight or initial alignment has to be provided, since the various possibilities of adjustment offered to the user do not enable the orientation of the line of sight in the reference frame of the sensor on the
20 helmet to be known a priori. In order to do this, a sensor measurement is acquired by the device when the pilot aims a predefined direction tied to the wearer, for example when the pilot aims a collimated reticule. Let L_{vo} be this predefined direction, called initialization direction, and let M_o be the sensor measurement during
25 this initialization phase; the corresponding measurement M_{co} in the cartography reference frame is calculated and the initialization matrix is written as: $I^{-1} = M_{co}M_o^{-1}$.

In addition, when the cartography reference frame
30 is not that of the wearer, it is necessary to carry out a change of reference frame, called "harmonization", characterized by a harmonization matrix H .
and thus:

$$L_v = H R I^{-1} L_{vo}$$

35 or also $L_v = H (McM^{-1}) (MoM_{co}^{-1}) H^{-1} L_{vo}$.

The terms R and I should be able to be accurately approximated using the function F_r consisting of the parameters of the previously described modelling. In practice, the application of this function to this step

of the method may turn out to be ineffective because of the helmet-tied disruptive elements such as, for example, the cathode ray tubes.

As a consequence, a step of compensation of the helmet-tied disruptive elements is also implemented, according to the same approach as that described hereinabove (in order to take into account the cockpit-tied disruptive element or those due to defects of the transmitter or of the sensor). In order to do this, a set of measurements is carried out, with the helmet, in several uniformly spaced points and in various mechanically known orientations of the helmet, one of these orientations coinciding with the approximate orientation of the sight direction called the initialization sight direction L_{vo} .

The application of the first function F_p makes it possible to determine a first approximation of I and of each sensor rotation associated with the various orientations, and thus makes it possible to define a first approximation of the orientation of the line of sight by (G_1, S_1, R_1) .

At this level of the algorithm, the result, although not accurate, is already significantly independent of the value of I of the initialization in actual use. In fact, the product RI^{-1} , irrespective of the mounting of the sensor on the helmet, is always tied to the line of sight. The value of I found during the cartography corresponds to a particular adjustment of the helmet.

A function F_r taking into account the presence of the helmet and directly modelling the theoretical line of sight (G_2, S_2, R_2) from G_1, S_1, R_1 and $r^T t_{MM}$ is then determined.

Figure 2 illustrates, in a combined manner, the various steps of the modelling phase of the orientation determination method according to the invention in its first version indicated hereinabove:

- The first step is the step of acquisition of measurement matrices $M_1 \dots M_n$ for a set of n positions of m , for a given orientation of the sensor;

- The second step 12 is the identification of the matrix P with the measurement matrix (M_c) corresponding to the position of the sensor coinciding with the reference frame of the cartography;

5 - The third step 13 is the calculation of r , then of the matrix $r^4(P)$ as indicated hereinabove;

- The fourth step is the step of calculation, for all the measurement matrices M_i of $(r^7 {}^t M_i M_i) = r^7 ({}^t M_i) (M_i)$ for $i = 1$ to n ;

10 - The fifth step 15 is the step of calculation of the n sets of regressors $(E_i) = (e_1 \dots e_k)_i$ for $i = 1$ to n ;

- The sixth step 16 is the step of the solution of the 9 systems of equation $P = E.A$ in the least-squares sense, in order to determine the sets of coefficients $(a_0 \dots a_k)_1 \dots (a_0 \dots a_k)_n$, forming the modelling function F_p ;

20 - The seventh step 17 makes it possible to find, from this modelling function, a first approximation of the cartography matrix M_c and therefore of the sensor rotation [lacuna] respect to the reference frame of the cartography $[G_1, S_1, R_1]$.

This step terminates the initial measurement level.

25 Next, for the level called "angular" level, a step 18 of acquisition of measurements for various known orientations of the sensor is carried out.

A calculation step 19 then makes it possible to seek the overall function F_r from these measurements.

30 A variant of the method according to the invention, making it possible to avoid the first step of acquisition of measurements (sensor in a fixed orientation and moved alone), consists in calculating, for each with-helmet measurement, a virtual measurement matrix M_v such that: $L_v = H M_v M^{-1} I^{-1} H^{-1} L_v o$.

35 I may, of course, be determined from a cartography with the sensor in a fixed orientation and from the corresponding function F_p . But it is preferable to determine it by an iterative method, as described

hereinbelow.

At each phase of the iteration, the matrix of rotation I of (G, S, R) chosen leads to a series of virtual measurements M_v from which a function F'_p is calculated, by optimization, so that $M_v M^{-1} I L_v$ is as close as possible to L_v , through the relationship $r^4 M_v = F'_p(r^7 t_{MM})$.

Following the iteration, the value of I and, simultaneously, the associated virtual measurements M_v are obtained.

The virtual measurements have an advantage compared to the previous measurements since they erase the distortion tied to the rotation of the sensor and integrate the deformations due to the helmet-tied disruptive masses.

In addition, the iterative search for I makes it possible to avoid the phase of initial measurements using the sensor alone in a fixed orientation.

Finally, the function F'_p is also optimized. The calculation time for the modelling is obviously slightly longer, while still remaining acceptable, because of the optimization of I .

The last step then remains the calculation of the function F_r directly modelling the theoretical line of sight from the best function F'_p which is produced from the same measurements.

The method is also suitable to direct correction of the optical distortions tied to the wearer's windshield (or canopy), during the sighting. In order to do this, these distortions are introduced during the determination of F_r , either by calculation or by actual test sightings, automatically or under control by the pilot.

One advantage of the method according to the invention is that the prior determination of a compact modelling function makes it possible to take into account the aberrations of a magnetic position and orientation detection system when such a system is used in a disruptive metallic environment, of the helicopter-cabin type. This compact modelling function is determined from

experimental measurements carried out for known positions of the sensor reference frame or directly from the line of sight. Next, in flight, the real-time use of the system is rapid, leads to reliable measurements and requires only a small amount of memory space in the onboard system.

The invention is not limited to the embodiments described precisely hereinabove. In particular, at the measurement level, which results in obtaining the modelling parameters from the reference measurements, the identification of the components of the measurement with a polynomial has been described as being carried out by linear regression over the 6 terms of $r^7 {}^tMM$.

In order to improve this step, it is possible to carry out a linear regression over a larger number of terms, for example 9, by adding to the 6 terms of $r^7 {}^tMM$ the 3 on-line scalar products of the matrix M, these terms being significant of the rotation, or else 3 terms μ_i defined by $r^4 (M)_{ii} = r^7 \mu_i ({}^tMM)_{ii}$, that is to say terms connecting the diagonal terms of M to the diagonal terms of tMM . In both these cases, the function F_p is then determined from 220 regressors.

Another possibility consists in using the terms μ_i described hereinabove, except for the products where no term of the matrix tMM appear [sic]. For these products, the μ_i are replaced by the on-line scalar products of the matrix M.

In addition, it has been indicated hereinabove that the search for the coefficients tying a component of P to the various terms of tMM was facilitated by homogenization of the type:

$$r^4 P = F_p(r^7 {}^tMM).$$

In practice, in a manner similar to that described for the optimization of I in the variant described, it is possible to carry out an iterative optimization (by the FIBONACCI method, for example) on the exponent of r. Experience shows that this optimization can lead to replacing r^7 by r^{ex} where ex has a non-integer value, for example of between 6.5 and 7,

which may depend on the environment.

Moreover, as regards the modelling of the angular deviations and the calculation of the line of sight which results from the precise rotation, a simplification making it possible to save in time the [sic] calculation may be implemented. In order to do this, the 3x3 matrix, $ROT = McM^{-1}MoMco^{-1}$ is calculated and the 9 terms of this matrix ROT are used as regressors for the direct modelling of angular deviations on G, S or R. F_r is then such that G (or S , or R) = $F_r(ROT)$.

A similar method consists in modelling the deviations on the terms of the matrix ROT itself, each component of the matrix $ROT = McM^{-1}MoMco^{-1}$ being expressed using a polynomial composed of the 9 components coming from the first step. The angles are then extracted from the matrix after regression.

The reader will easily understand that other modifications may be made, especially in order to carry out more rapid calculations or to improve the accuracy of the results obtained without departing from the scope of the invention, that is to say always by carrying out a prior phase of modelling the complex relationships connecting the actual measurements to the position of the sensor, or to the orientation of the line of sight to which it is tied.

In an embodiment example of the variant using predetermined orientations of the line of sight, the modelling has been obtained from 85 orientations and, for each of these orientations, 27 measurement points (i.e. 27 positions of m), that is 9 points equidistributed over 3 equidistant planes forming a cubic mesh whose spacing is of the order of 3 to 4 cm. The measurements were made for values of

$R = 0^\circ$ and $G = \{90^\circ, 60^\circ, 30^\circ, 0^\circ, -30^\circ, -60^\circ, -90^\circ\}$
 $S = \{40^\circ, 20^\circ, 0^\circ, -20^\circ, -40^\circ\}$ for $R = 0$
and $R = \{+10^\circ, -10^\circ\}$ and $G = \{90^\circ, 45^\circ, 0^\circ, -45^\circ, -90^\circ\}$
and $S = \{40^\circ, 20^\circ, 0^\circ, -20^\circ, -40^\circ\}$
that is 2295 measurement points m . The calculation time necessary for the prior modelling is a function of the

power of the calculation means. By way of example, in order to obtain F_p using 220 regressors, the duration of the calculation may be of the order of 3 hours; using 84 regressors, the calculation of a modelling function may be of the order of 5 minutes.



CLAIMS

1. Method for determining an orientation tied to a system which is mobile in a defined space, using a magnetic position and orientation detection system which includes a transmitter formed by three orthogonal coils having a fixed position in the defined space and a sensor, formed by three orthogonal coils, which is attached to the mobile system, r being the distance between the origin (0) of the transmitter reference frame and the origin (m) of the sensor reference frame, a detection cycle consisting in transmitting in succession in the three coils of the transmitter and in measuring the field components generated in the coils of the receiver, the method including a prior phase of modelling the defined space, which consists

- in carrying out measurements of the magnetic fields in the sensor for a set of known positions of the mobile system with respect to a reference frame called cartographic reference frame and in acquiring, for each point corresponding to these positions and for a given orientation of the sensor, a measurement matrix M , and being characterized in that the prior modelling phase in addition consists

- in calculating modelling parameters deduced from the reference measurements at each said point by identification, by linear regression, of the components of a measurement matrix (P) corresponding to the position of the sensor coinciding with the cartographic reference frame and taken as base, with polynomials obtained from regressors calculated from the terms of the matrices tMM , themselves calculated from the various measurement matrices M , the products tMM being assumed to be invariant because the measurement matrices are deduced from each other by rotation, in order to deduce therefrom the relative rotation of the sensor (G_1, S_1, R_1), in the cartographic reference frame of the reference measurements, these modelling parameters forming a compact modelling function (F_p) of the disruptive effects, which is a function of the position,



and in that, during use, the current orientation of the mobile system is determined directly from the position modelling function (F_p).

2. Method according to Claim 1, characterized in that the prior modelling phase is completed by a second phase in order to improve the accuracy of the relative rotation obtained at the previous step, by modelling the angular deviations between true rotations (G_2, S_2, R_2) and the approximate sensor rotation in the previous phase (G_1, S_1, R_1), this precise rotation enabling the current orientation (L_v) to be calculated.

3. Method according to Claim 1, characterized in that the current orientation is calculated from the sensor rotation and in that a second phase is implemented in order to improve the accuracy of the current orientation (L_v) by modelling the deviations between true orientations and the calculated corresponding orientations.

4. Method according to one of the preceding claims, characterized in that the calculation of the current orientation (L_v) from the sensor rotation includes an initial alignment step from a known position of the orientation (L_{v_0}) [sic], in order to determine an initialization matrix (I) characterizing the rotation of the known position of the orientation with respect to the cartographic reference frame.

5. Method according to Claim 1, characterized in that the modelling parameters result from the identification of the r^4P components with F_p ($r^{ex} t_{MM}$) where F_p is a polynomial function of the $r^{ex} t_{MM}$ components, ex being an exponent lying between 6.5 and 7, the identification being carried out by the method of least squares.

6. Method according to Claim 5, characterized in that the exponent ex is optimized in order to minimize the deviations.

7. Method according to Claim 6, characterized in that the modelling parameters result from the identification, by linear regression, of the r^4P components with polynomials obtained from regressors



calculated from the 6 terms of the tMM matrices and from the on-line scalar products of the matrices M .

8. Method according to Claim 1, characterized in that the modelling parameters result from the
5 identification, by linear regression, of the r^4p components with polynomials obtained from regressors calculated from the 6 terms of the symmetric matrices tMM and from the terms μ_i defined by $r^4(M)_{ii} = r^7\mu_i t^{}{}^tMM_{ii}$ [sic], $r^4(M)_{ii}$ being the diagonal terms of the matrix r^4M
10 and ${}^tMM_{ii}$ being the diagonal terms of the matrix $r^7{}^tMM$.

9. Method according to Claim 1, characterized in that the compact modelling function (F_p) is calculated from measurement matrices associated with a set of
15 orientations defined from a fixed orientation, virtual measurement matrices (Mv) being deduced from these defined orientations (Lv) and from corresponding measurement matrices (M).

10. Method according to Claim 9, characterized in that an alignment intended to evaluate the initial
20 rotation (I) of the fixed orientation (Lvo) with respect to the cartographic reference frame is carried out at the same time as the calculation of the virtual measurement matrices (Mv) by an iterative method making it possible to optimize a compact modelling function F'_p such as $r^4Mv = F'_p(r^7{}^tMM)$, and $MvM^{-1}ILvo$ being the closest possible to
25 Lv .

11. Method according to one of Claims 2 and 3, characterized in that the modelling of the angular
30 deviations is carried out from known true rotations (G_2 , S_2 , R_2) and from the associated mapped measurement matrices, by identification of the known true rotation components (G_2 , S_2 , R_2) with polynomials constituted from regressors calculated on the terms of the matrices $r^7({}^tMM)$ and on the angles of the approximate rotations
35 (G_1 , S_1 , R_1), the resulting coefficients forming the modelling function (F_r) of the disruptive effects, which is a function of the rotation.

12. Method according to one of Claims 2 and 3, characterized in that a rotation matrix $ROT = McM^{-1}MoMCo^{-1}$



is calculated from each measurement matrix M , M_c being the resulting matrix of M after application of the position modelling function (F_p) and M_o and M_{co} being the matrices M and M_c for a known fixed initialization orientation (L_{vo}), and in that the modelling of the angular deviations is carried out by identification of the known true rotations (G_2 , S_2 , R_2) with polynomials constituted from regressors calculated on the terms of the matrices ROT , the resulting coefficients forming the modelling function (F_r) of the disruptive effects, which is a function of the rotation.

13. Method according to either of Claims 2 and 3, characterized in that a rotation matrix $ROT = M_c M^{-1} M_o M_{co}^{-1}$ [sic] is calculated from each measurement matrix M , M_c being the resulting matrix of M after application of the position modelling function (F_p) and M_o and M_{co} being the matrices M and M_c for a known fixed initialization orientation (L_{vo}), and in that the modelling of the angular deviations is carried out by identification of the terms of the matrix ROT with polynomials constituted from regressors calculated on the terms of the matrix ROT , the resulting coefficients forming the modelling function (F_r) of the disruptive effects, which is a function of the rotation.

14. Device for determining an orientation related to a mobile system, including a transmitter (1) formed by three orthogonal magnetic coils having a fixed position in a defined space and a sensor (2) formed by three orthogonal coils, attached to the mobile system, which device includes:

- means for moving the sensor and the orientation which is related to it according to a set of known positions, means (20) of transmission of field by the transmitter (1) and of measurement of field by the sensor (2), these means being coupled to calculating means (10), in order to carry out, in a modelling phase, measurements of the magnetic fields in the sensor for a set of known positions of the mobile system with respect to a reference frame called the cartographic reference frame



and to acquire, for each point corresponding to these positions and for a given orientation of the sensor, a measurement matrix M , and to carry out, during use, current measurements of the magnetic fields in the sensor, the device being characterized by

5 - a modelling calculating machine (60) coupled to the calculating means (10) via an interface circuit (50) which contains, in the form of software, the algorithms intended for the prior modelling of the corresponding
10 space in order to calculate modelling parameters deduced from the reference measurements at each said point by identification, by linear regression, of the components of a measurement matrix (P), corresponding to the position of the sensor coinciding with the cartographic
15 reference frame and taken as base, with polynomials obtained from regressors calculated from the terms of the matrices tMM , themselves calculated from the various measurement matrices M , the products tMM being assumed to be invariant because the measurement matrices are deduced
20 from each other by rotation, in order to deduce therefrom the relative rotation of the sensor (G_1, S_1, R_1) in the cartographic reference frame of the reference measurements, these modelling parameters forming a compact modelling function (F_p) of the disruptive
25 effects, which is a function of the position, the current orientation of the mobile system during use being determined directly from the current measurements of the magnetic fields in the sensor and from the position modelling function (F_p).