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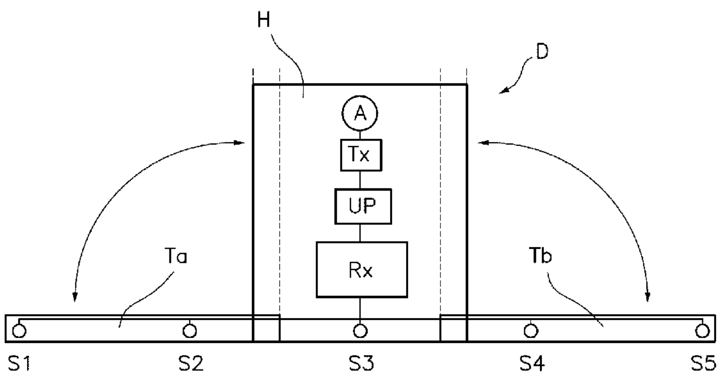

Fig.2

(57) Abstract: A method and a portable rescue device for locating avalanche victims The method comprises performing: a) searching, with a portable electromagnetic signal receiver (Rx),an electromagnetic signal emitted by a portable electromagnetic signal transmitter (Tx); b) a first tracking step for measuring and following the magnetic field of the electromagnetic signal emitted by the portable electromagnetic signal transmitter; and c) a second tracking step comprising determining the location of the portable electromagnetic signal transmitter by estimating the spatial position thereof from output signals provided by a plurality of magnetic vector sensors (S1-SM) of the portable electromagnetic signal receiver (Rx), arranged forming an array, by exploiting their spatial diversity. The portable rescue device is adapted to implement the method of the invention.

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A method and a portable rescue device for locating avalanche victims

Field of the Art

The present invention generally relates, in a first aspect, to a method for locating avalanche victims, based on measurements of electromagnetic signals emitted from a transmitter carried by a victim, and more particularly to a method comprising performing a final approach step that exploits the spatial diversity provided by an array of magnetic vector sensors.

A second aspect of the invention relates to a portable rescue device for locating avalanche victims adapted to implement the method of the first aspect of the invention.

Prior State of the Art

A fundamental problem in the rescue of avalanche victims is the little time that an injured person may remain alive when buried by snow after being struck by an avalanche. Several studies agree that the chance of survival drops sharply after 15 minutes of being buried. That is why the rescues organized by outside groups are not effective in saving the lives of the injured, and therefore the rescue has to be done by those in the group who have not been buried by the avalanche, what is known as self-rescue.

Given the time it takes to dig up an avalanche victim, the location of a victim has to be resolved in a maximum of only 5 minutes. For this reason, one of the main objectives in designing victim localization devices is that the search method implemented by the device is as efficient as possible in terms of speed of localization. Another important objective is to reduce as much as possible the complexity of its use, so that factors such as panic, fatigue, adverse conditions or inexperience, cannot prevent the rapid location of the victim.

Currently these self-rescue devices are known as Avalanche Victim Detector (AVD) or Avalanche Transceiver (AT), and consist of an electromagnetic transmitter-receiver equipped with three (or less) orthogonal coils acting like antennas, and are governed by the rules laid down in the standard ETSI EN 300 718. By default, the device operates in transmit mode, radiating a magnetic vector field $\mathbf{B}(t)=(B_x(t), B_y(t), B_z(t))$ through one of the coils that can be modelled as the field generated by a magnetic dipole. The device uses a modulation A1A (carrier on/off) at the frequency 450KHz.

In case of an avalanche, the group members who have not been buried activate the receive mode of the device, and start to search from the receiver measures at the three coils. These three mutually orthogonal coils behave like a single antenna capable of obtaining the three vector components of $\mathbf{B}(t)$, that is, they behave like a single magnetic vector sensor. Since the vector $\mathbf{B}(t)$ is tangent to the field line of the emitted field, simply by following the direction of $\mathbf{B}(t)$ as its measure is being updated is enough to trace a path that coincides with said field line, which leads to the emitter. If there are L victims, then L-1 received signals are blocked to follow only the field line of one of them. By performing this protocol in an iterative manner the different victims are being encountered.

Two drawbacks affect this search method directly increasing the search time. First, the followed path is not straight. This makes the ride a little longer, and it does not allow the user to get an idea of the area where the victim can be until it is very close, because the directions change, although slightly, unpredictably for the user. Second, the direction of $\mathbf{B}(t)$ can vary greatly near the receiver, which can make the rescuer be easily confused, especially without proper training and a familiarization with the device. This second current limitation makes the known search method for the last few meters not to be based on the tracking of the field lines, but on power measurements only, which is known as fine search. As the fine search is still quite inaccurate, it leads to a time-consuming subsequent step known as pinpointing that consists on probing systematically starting from the estimated location until the victim is located. Left view of Fig. 1 illustrates the trajectories followed by a rescue user according to this conventional method, and will be described in more detail posteriorly.

There are several patent documents disclosing different rescue portable rescue devices and associated search methods, based on the detection of RF signals emitted by a transmitter of the avalanche victim, some of which emit a magnetic field pattern, acting as a magnetic dipole. Some of said patent documents based on the detection of said magnetic field patterns are cited next and their relevant background is briefly described.

US7116272B2 discloses a system and method for locating an avalanche victim based on the RF reception of the transmitted field as emitted by a distress beacon carried by the victim, during a search and rescue operation. It provides point to point directional data as to the direction of the RF field source based on flux field characteristics, and also an estimated distance between the searcher's receiver and the victim's transmitter field source using path loss slope and/or triangulation, where the estimation of distance is based upon field signal strength transmitted by the victim's transmitter avalanche or field strength changes in a certain direction with regard to the field lines and/or over a certain distance. Neither a direct estimation/calculation of the magnetic dipole source position is disclosed in US7116272B2 nor the use of an array of magnetic vector sensors.

US6246863B1 discloses another rescue device for locating persons buried by avalanches also based on signal strength, which operates in either a transmit mode or a receive mode, and has a case and a harness constructed from belts for securing the case to the individual, where the rescue device switches on or off and changes its operating mode, between a transmission mode and a receiving mode, based on the locking or unlocking of the belts to the case. The device includes a display which provides graphic information to expedite searching, including graphical information related to when a coarse search or a pin-point search should be conducted, when the stage of a multistage amplifier should be changed, when the rescue device needs to be reoriented to obtain maximum signal strength, the signal strength as a bar graph and an estimated distance to the buried transmitter. Neither an array of magnetic vector sensors for providing spatial diversity nor a direct calculation of the transmitter position is disclosed in US6246863B1.

US2005151662 discloses an avalanche transceiver comprising a receiver including three mutually orthogonal receiving antennas each capable of receiving a radio signal at a predetermined frequency which are somewhat mutually orthogonal, and a processor that is capable of: selecting one or more of the said antennas, controlling the sensitivity of an antenna, and digitally processing received signals to measure signal strength and/or relative polarity for providing indications of the received flux field regarding proximity, horizontal alignment and vertical alignment. The provision of such three antennas is for always receiving the emitted signal in close proximity to a burial regardless of the orientation of the buried transmitter. Neither an array of magnetic vector sensors for providing spatial diversity nor a direct estimation/calculation of the transmitter position is disclosed in US2005151662.

US6167249 and US6484021 both disclose a rescue transceiver apparatus for transmitting a signal to and receiving a signal from another rescue transceiver apparatus is provided. The apparatus comprises a housing and a radio signal transmitter for the transmission of a radio signal in a transmitting mode with a first predetermined frequency with the radio signal transmitter being mounted within the housing. The receiver comprises first and second antennae arranged substantially perpendicular to each other, and a virtual third antenna being derived from phase information generated by the first antenna and the second antenna. The first antenna, the second antenna, and the third virtual third antenna provide three-dimensional vector analysis by the receiver of a predetermined frequency received from the radio transmitter. Neither an array of magnetic vector sensors for providing spatial diversity nor a direct calculation of the transmitter position is disclosed in US6167249 nor in US6484021.

Description of the Invention

It is an object of the present invention to provide an alternative to the prior state of the art, which the purpose of achieving a faster and easier rescue of an avalanche victim than those provided by the devices and methods of the state of the art.

To that end, the present invention relates, in a first aspect, to a method for locating avalanche victims, comprising performing sequentially the next steps, in a known manner:

a) an initial step comprising, a user carrying a portable electromagnetic signal receiver, performing an electromagnetic signal search by moving around a first area, away from the victim, in order to detect, by its reception with the portable electromagnetic signal receiver, an electromagnetic signal (generally the magnetic field included therein) emitted by a portable electromagnetic signal transmitter carried by an avalanche victim and acting as a magnetic dipole;

b) a first tracking step, started after said electromagnetic signal has been detected and comprising measuring, with said portable electromagnetic signal receiver, the magnetic field emitted by said portable electromagnetic signal transmitter, and moving, said user carrying said portable electromagnetic signal receiver, following a curve path coincident with the magnetic field line of said emitted magnetic field approaching to the victim through a second area closer thereto; and

c) a second tracking step performed after said first tracking step, comprising moving the user carrying the portable electromagnetic signal receiver through a third area, even closer to the victim, for finally locating the victim.

Contrary to the known methods, the method of the first aspect of the invention comprises, in a characteristic manner, providing and using, as said portable electromagnetic signal receiver, a portable electromagnetic signal receiver with an array of magnetic vector sensors arranged for receiving said electromagnetic signal with spatial diversity, and said step c) comprises, based on the measurement of said magnetic field performed with part or preferably all of said magnetic vector sensors, determining the location of said portable electromagnetic signal transmitter by estimating the spatial position of said magnetic dipole from output signals provided by said magnetic vector sensors of said array, exploiting their spatial diversity through one or more array signal processing techniques.

The method comprises arranging said magnetic vector sensors of said array physically separated one from another by a minimum distance to provide said spatial diversity when they are at or below a predetermined distance from the portable electromagnetic signal transmitter.

The method of the first aspect of the invention comprises performing said step a) by using the output signal of one of said magnetic vector sensors, and if no signal is detected with only said magnetic vector sensor (or detected poorly), performing a detection by adding to each other the output signals provided by, preferably, each of the magnetic vector sensors when receiving said electromagnetic signal emitted by the portable electromagnetic signal transmitter, thus achieving a signal-to-noise ratio much higher than the one achieved in the state of the art methods which perform said step a) with only one output signal, therefore reducing the time taken for performing step a), in comparison with the conventional search methods. For this step a), only detecting the electromagnetic signal is of interest. Moreover, in most cases there exists a long distance to the avalanche victim and hence the spatial diversity provided by the magnetic vector sensors is not high. As a result, spatial diversity is not exploited in step a).

For another embodiment, step a) is performed, from the start to the end thereof, by performing said detection using array processing different than addition with the output signals provided by each of the magnetic vector sensors (or at least by two or more of them).

The method of the first aspect of the invention comprises performing said step b) based on the measurement of said magnetic field performed with at least one of the magnetic vector sensors and/or based on the measurement of said magnetic field performed by adding to each other the output signals provided by each of said magnetic vector sensors when measuring said magnetic field.

Particularly, for an embodiment, the method comprises starting performing step b) based on the measurement of the magnetic field performed by adding to each other the output signals provided by each of the magnetic vector sensors when measuring the magnetic field and, once the output signal of one of the magnetic vector sensors so allows it, continuing performing step b) based on the measurement of the magnetic field performed with only said one of said magnetic vector sensors.

For an embodiment, the method of the first aspect of the invention comprises automatically stopping step b) and starting step c) upon considering, based on their analysis, that the output signals of said magnetic vector sensors provide a degree of spatial diversity above a certain threshold and/or that the magnetic field lines information calculated by said portable electromagnetic signal receiver does not allow performing the first tracking step with a certain amount of reliability.

The trajectory followed by the user at step c) can be a straight line (if possible due to geographical obstacles), hence providing a quicker approach to the victim than the curve trajectory of step b). Therefore, the sooner said spatial diversity is considered as allowing to start step c), the sooner step b) is stopped and step c) is started, thus reducing the time the user is arriving to the avalanche victim. Although the method of the first aspect of the invention has been described as including said step b), ideally it could work doing without it, i.e. passing directly from step a) to step c) if, when the electromagnetic signal has been received at step a) by the magnetic vector sensors, the spatial diversity provided thereby already allows the start of step c) that could happen, for example, if the victim is near the rescue user, or if the separation between the magnetic vector sensors is very high).

The trigger for activating step c) is preferably implemented automatically, based on the analysis of one or several parameters of the output signals of the magnetic vector sensors, such as their magnetic powers and directions.

A second aspect of the invention relates to a portable rescue device for locating avalanche victims, comprising:

- electromagnetic receiving means for receiving an electromagnetic signal emitted by a portable electromagnetic signal transmitter carried by an avalanche victim and acting as a magnetic dipole, and measuring the magnetic vector field emitted by said portable electromagnetic signal transmitter, and

- processing means connected to said electromagnetic receiving means for receiving and analysing electrical output signals provided thereby and providing to a user of the portable rescue device, through indication means thereof, indications regarding the result of said reception and analysis to allow him to perform said moving of the user through said first, second and third areas towards the victim of steps a), b) and c) of the method of the first aspect of the invention.

Depending on the embodiment, said indication means comprise at least one of a display (for displaying graphical information including, for example, a three-dimensional map of the search and rescue areas and the updating estimated locations of the victim) and acoustic means (for emitting acoustic signals differing in, for example frequency, volume or pitch, for indicating the different situations of the search).

Contrary to the known portable rescue devices for locating avalanche victims, in the one of the second aspect of the invention, in a characteristic manner, its receiving means comprise an array of magnetic vector sensors arranged for receiving said electromagnetic signal with spatial diversity, and said processing means implement the method of the first aspect of the invention for performing at least said estimation of the spatial position of said magnetic dipole exploiting the spatial diversity of the output signals of the magnetic vector sensors.

For a preferred embodiment, each of said magnetic vector sensors is capable of performing a three-axes magnetic vector measurement.

Depending on the embodiment, each of said magnetic vector sensors is a magnetoresistive sensor, such as an Anisotropic Magnetorresistive Sensor (ARM), or an antenna comprising three orthogonally arranged magnetic coils.

Said magnetic vector sensors of said array are physically separated one from another by a minimum distance to provide said spatial diversity when they are at or below a predetermined distance from the portable electromagnetic signal transmitter. The higher said minimum distance is the further from the avalanche victim the exploitation of spatial diversity of the output signals of the magnetic vector sensors can be used, thus reducing the time for locating the victim.

Depending on the embodiment, said array include magnetic sensors arranged occupying at least one line (linear array), one plane (planar array), or any other general geometry such a surface (conformal array).

Optionally, for an embodiment, the portable rescue device of the second aspect of the invention comprises adjusting means for adjusting different operating parameters of the device regarding the implementation of each of steps a), b) and c), such as predetermined and adjustable threshold values for automatically triggering the start of step c).

For an embodiment, the portable rescue device of the second aspect of the invention comprises a main casing housing at least said processing means and part of said receiving means, and a support onto which said magnetic vector sensors are attached, such that they adopt the physical separation with each other which provides said spatial diversity.

Said elongated support is, for an embodiment, at least one deployable and/or extensible arm connected to said main casing and onto which at least part of said magnetic vector sensors are attached such that they adopt the physical separation with each other which provides said spatial diversity when said at least one arm is at the deployed and/or extended position.

For another embodiment, said elongated support is a flexible band to be worn by said user in an extended position, such as diagonally crossing his chest.

The portable rescue device of the second aspect of the invention further comprises, for a preferred embodiment, electromagnetic transmission means and selection means, the latter for alternately:

- activating said electromagnetic receiving means for receiving said electromagnetic signal emitted by a portable electromagnetic signal transmitter carried by an avalanche victim, for allowing the user of the portable rescue device act as an avalanche victim locator by activating the device in a receiving mode; or

- activating said electromagnetic transmission means for transmitting said electromagnetic signal, for allowing the user of the portable rescue device act as a potential avalanche victim to be located by activating the device in a transmitting mode.

In other words, for the above indicated embodiment, a plurality of portable rescue devices according to the second aspect of the invention can be used by a group of users which, before an avalanche, activate its transmitting mode (as they are potential avalanche victims), and after an avalanche has occurred, those users which are not victims of said avalanche activate their portable rescue devices in their receiving modes in order to locate the victim or victims of said avalanche which are carrying respective portable rescue devices still activated in their transmitting modes.

The method and the rescue device of the present invention allow the estimation of the positions of multiple avalanche victims simultaneously.

Particularly, for an embodiment of the method of the first aspect of the invention, step c) comprises simultaneously estimating the spatial positions of multiple magnetic dipoles, associated to multiple avalanche victims, from output signals provided by the magnetic vector sensors of the array, exploiting their spatial diversity through one or more array signal processing techniques.

Brief Description of the Drawings

The previous and other advantages and features will be better understood from the following detailed description of embodiments, with reference to the attached drawings, which must be considered in an illustrative and non-limiting manner, in which:

Fig. 1 shows the trajectories followed by a rescue user to locate an avalanche victim, according to a conventional method (left view) and according to the method of the first aspect of the invention (right view);

Fig. 2 shows the architecture of the portable rescue device of the second aspect of the invention for another embodiment, being carried by a user, where the sensors of the array of magnetic vector sensors are attached to a band worn by the user;

Fig. 3 schematically shows the portable rescue device of the second aspect of the invention, including its internal elements, for an embodiment for which most of the sensors of the array of magnetic vector sensors are attached to two deployable arms; and

Fig. 4 shows a processing scheme of the receiving means of the portable rescue device of the second aspect of the invention.

Detailed Description of Several Embodiments

Left view of Fig. 1 shows the trajectories followed by a rescue user to locate an avalanche victim, according to a conventional method, and includes the next stages, indicated in Fig. 1, left view as 1, 2, 3 and 4:

Stage 1 – Signal search: With the current sensitivity of the antenna used, the conventional device is able to detect signal at about 50 meters approximately. Until the signal is not detected a search for said signal is performed by the user walking through the searching area according to the meandered path depicted in Fig. 1 left view, to pick up the trail, i.e. to detect the signal. This stage is inevitable but undesirable because it wastes time. In order to reduce the lasting of this stage and hence not wasting time, the sensitivity of the receiver must be as high as possible.

Stage 2 – Coarse search: Once the signal has been detected, the magnetic field vector is calculated and its direction is followed by the rescuer. The rescuer must walk in the two directions of the field line to see if the field power decreases or increases, and choose the direction where the field increases, otherwise he moves away from the victim. As the path is not straight, but curved, it causes wasting some time.

Stage 3 – Fine search: This stage starts when following the field lines of the magnetic field is no longer reliable, and consists in searching for the maximum power above the surface crossways and in straight lines, and mark the point with crossed poles. This stage is time-consuming and inaccurate.

Stage 4 – Pinpointing: The rescuer pinpoints the ground with a probe starting from the marked crossed poles in order to accurately locate the victim. Time is wasted for this manual stage.

For comparison with said conventional search method, right view of Fig. 1 shows the trajectories followed by a rescue user to locate an avalanche victim according to the method of the first aspect of the invention, which includes the next stages, indicated in Fig. 1, right view as 1, 2 and 3:

Stage 1 (referred above as step a)) – Signal search: The outputs of the *M* magnetic vector sensors of the array are directly added up due to the low spatial diversity, which improves the signal-to-noise ratio by a factor *M*. Thus the sensitivity is improved, and therefore the signal is detected earlier than in the conventional method. As a result, the meandered path that the rescuer must follow is shorter than the one of left view of Fig. 1, and the time wasted in this stage is thus reduced. The comparison with the conventional method has been done assuming that each of the magnetic vector sensors of the array has the same sensitivity as the coil used in the conventional search method.

Stage 2 (referred above as step b)) – Coarse search: Being away from the victim, spatial diversity is still not good enough and it is preferable to use the output of the *M* magnetic vector sensors just to calculate the magnetic field vector therefrom and follow its direction. This stage is only applied until the rescue user is close enough to the victim so that there exists enough spatial diversity. An adequate value for this distance is about 10 meters with the current technology and the standard being used. In the conventional method, in contrast, this stage has to be applied until the rescue user is about 2 meters away of the victim.

Stage 3 (referred above as step c)) – Fine search: Once the user is close enough to exploit spatial diversity, the position of the magnetic dipole (i.e. of the transmitter) is calculated and the rescuer follows a straight path to find it. It is faster than following a curve and there is no need of a probing stage.

The change between phase 2 and 3 of the proposed method is transparent to the user and is performed automatically by the portable rescue device. This is a very important advantage because it simplifies the location in essentially two phases, the signal search (1) and to follow a given direction by, for example, a display (2 and 3).

Fig. 2 depicts the device of the second aspect of the invention, for an embodiment for which it contains a loop (or more if desired) which is used as a transmitting antenna A of the transmitter Tx, and an array of M magnetic sensors S1-S5 arranged in a specific and known manner for reception and connected to the receiver Rx. Each of these sensors S1-S5 is capable of calculating the field vector received thereby. Thus, three mutually orthogonal coils would correspond to a single sensor. Another interesting option for its size and weight are magnetoresistive sensors, such as Anisotropic Magnetoresistive (AMR) sensors.

With this new architecture, spatial diversity existing in the *M* measures $\mathbf{B}_1(t)$, ..., $\mathbf{B}_M(t)$ of the field $\mathbf{B}(t)$ (see fig. 4) in the same receiver can be exploited and estimate the position $\mathbf{p}$ for the magnetic dipole generating the measured magnetic field. The positions $\mathbf{p}_1,\ldots,\mathbf{p}_L$ (see fig. 4) of *L* victims can also be estimated simultaneously.

Fig. 2 only illustrates an example of a possible architecture of the portable rescue device D of the second aspect of the invention, for an embodiment where its receiving means Rx include a linear array of five magnetic vector sensors S1-S5. In this case, optionally and to obtain a higher spatial diversity, the portable rescue device of the second aspect of the invention has two side extendable arms Ta, Tb where part of the magnetic vector sensors of the array are placed, particularly sensors S1, S2, S4 and S5. The sensor S3 is attached to the main casing H which houses the rest of elements of the device, including the processing means connected to the transmitter Tx and to the receiver Rx, in order to process the output signals coming therefrom. The block indicated as UP is used for illustrating, not only the processing means, but also control means for controlling the operation of the transmitter Tx and of the receiver Rx, and selection means for selecting if operating the device in the transmitting or in the receiving mode.

These arms Ta, Tb, which in Fig. 2 are shown deployed (their rest positions indicated by means of dotted lines in the side edges of main casing H), can be, for an embodiment, extendable (for example telescopically) to provide even more spatial diversity. Also, two more arms can be added to obtain an array on a two-dimensional surface, or even eight arms can be used for a three-dimensional array geometry. However, an armless device is also a right solution, for a less preferred embodiment, in which case the linear array could be distributed along one side of the main casing H, and a rectangular array could be distributed along all four sides of the main casing H.

Fig. 3 shows another embodiment, where the portable rescue device D comprises, attached to the main casing H, a flexible band T to be worn by the user (in the illustrated embodiment diagonally across his chest) such that the magnetic vector sensors of the linear array, in this case four sensors S1-S4, keep separated so as to provide the mentioned spatial diversity.

Fig. 4 shows the processing scheme of the receiver Rx. It will vary slightly depending on the type of magnetic vector sensor used in the array. In case the sensors measure the instantaneous field $\mathbf{B}_1(t)$, $\mathbf{B}_2(t)$, …, $\mathbf{B}_M(t)$, a down-conversion stage (I/Q decomposition) has to be performed together with a processing from the baseband signals $\mathbf{b}_1(t)$, $\mathbf{b}_2(t)$, …, $\mathbf{b}_M(t)$, by means of the processing means UP, as shown in Fig. 4. In this case, the baseband signals $\mathbf{b}_1(t)$, $\mathbf{b}_2(t)$, …, $\mathbf{b}_M(t)$ are complex. Although Fig. 4 only shows the I/Q decomposition of $B_{1x}(t)$, for the rest of components of $\mathbf{B}_1(t)$ ($B_{1y}(t)$, $B_{1z}(t)$) and also of $\mathbf{B}_2(t)$ and $\mathbf{B}_3(t)$, a respective I/Q decomposition is also performed.

In case the magnetic sensors calculate the envelope of the received field, or even directly the received power, such as some magnetic sensors integrated into a digital chip, the processing is directly applied to the measured signal, because it is already a baseband signal. In this case the baseband signal is a real signal.

A person skilled in the art could introduce changes and modifications in the embodiments described without departing from the scope of the invention as it is defined in the attached claims.

Claims

1.- A method for locating avalanche victims, comprising performing sequentially the next steps:

a) an initial step comprising, a user carrying a portable electromagnetic signal receiver (Rx), performing an electromagnetic signal search by moving around a first area, away from the victim, in order to detect, by its reception with the portable electromagnetic signal receiver (Rx), an electromagnetic signal emitted by a portable electromagnetic signal transmitter carried by an avalanche victim and acting as a magnetic dipole;

b) a first tracking step, started after said electromagnetic signal has been detected and comprising measuring, with said portable electromagnetic signal receiver (Rx), the magnetic field emitted by said portable electromagnetic signal transmitter, and moving, said user carrying said portable electromagnetic signal receiver (Rx), following a curve path coincident with the magnetic field line of said emitted magnetic field approaching to the victim through a second area closer thereto; and

c) a second tracking step performed after said first tracking step, comprising moving the user carrying the portable electromagnetic signal receiver (Rx) through a third area, even closer to the victim, for finally locating the victim;

wherein the method is **characterised** in that it comprises providing and using, as said portable electromagnetic signal receiver (Rx), a portable electromagnetic signal receiver with an array of magnetic vector sensors (S1-SM) arranged for receiving said electromagnetic signal with spatial diversity, and in that said step c) comprises determining the location of said portable electromagnetic signal transmitter by estimating the spatial position of said magnetic dipole from output signals provided by said magnetic vector sensors (S1-SM) of said array, exploiting their spatial diversity through at least one array signal processing technique.

2.- The method of claim 1, comprising performing, at said step c), a three-axes magnetic vector measurement with each of said magnetic vector sensors (S1-SM).

3.- The method of claim 1 or 2, comprising arranging said magnetic vector sensors (S1-SM) of said array physically separated one from another by a minimum distance to provide said spatial diversity when they are at or below a predetermined distance from the portable electromagnetic signal transmitter.

4.- The method of any of the previous claims, comprising performing said step a) by using the output signal of one of said magnetic vector sensors (S1-SM) and if no signal is detected with only said magnetic vector sensor, or detected poorly, performing a detection using array processing with the output signals provided by each of said magnetic vector sensors (S1-SM) when receiving said electromagnetic signal emitted by the portable electromagnetic signal transmitter.

5.- The method of any of the previous claims, comprising performing said step b) based on the measurement of said magnetic field performed with at least one of said magnetic vector sensors (S1-SM) and/or based on the measurement of said magnetic field performed by adding to each other the output signals provided by each of said magnetic vector sensors (S1-SM) when measuring said magnetic field.

6.- The method of claim 5, comprising starting performing said step b) based on the measurement of said magnetic field performed by adding to each other the output signals provided by each of said magnetic vector sensors (S1-SM) when measuring said magnetic field and, once the output signal of one of said magnetic vector sensors (S1-SM) so allows it, continuing performing step b) based on the measurement of the magnetic field performed with said one of said magnetic vector sensors (S1-SM).

7.- The method of any of the previous claims, comprising automatically stopping said step b) and starting said step c) upon considering, based on their analysis, that the output signals of said magnetic vector sensors (S1-SM) provide a degree of spatial diversity above a certain threshold and/or that the magnetic field lines information calculated by said portable electromagnetic signal receiver (Rx) does not allow performing the first tracking step with a certain amount of reliability.

8.- The method of any of the previous claims, wherein said step c) comprises simultaneously estimating the spatial positions of multiple magnetic dipoles, associated to multiple avalanche victims, from output signals provided by the magnetic vector sensors (S1-SM) of the array, exploiting their spatial diversity through said at least one array signal processing technique.

9.- A portable rescue device for locating avalanche victims, comprising:

- electromagnetic receiving means (Rx) for receiving an electromagnetic signal emitted by a portable electromagnetic signal transmitter carried by an avalanche victim and acting as a magnetic dipole, and measuring the magnetic vector field emitted by said portable electromagnetic signal transmitter, and

- processing means (UP) connected to said electromagnetic receiving means (Rx) for receiving and analysing electrical output signals provided thereby and providing to a user of the portable rescue device (D), through indication means thereof, indications regarding the result of said reception and analysis to allow him to perform said moving of the user through said first, second and third areas towards the victim of steps a), b) and c) of the method of any of the previous claims;

wherein the portable rescue device is **characterised** in that said receiving means (Rx) comprise an array of magnetic vector sensors (S1-SM) arranged for receiving said electromagnetic signal with spatial diversity, and in that said processing means (UP) implement the method of any of the previous claims for performing at least said estimation of the spatial position of said magnetic dipole exploiting the spatial diversity of the output signals of the magnetic vector sensors (S1-SM).

10.- The portable rescue device of claim 9, wherein each of said magnetic vector sensors (S1-SM) is capable of performing a three-axes magnetic vector measurement and is a magnetoresistive sensor or an antenna comprising three orthogonally arranged magnetic coils.

11.- The portable rescue device of any of claims 9 to 10, wherein said magnetic vector sensors (S1-SM) of said array are physically separated one from another by a minimum distance to provide said spatial diversity when they are at or below a predetermined distance from the portable electromagnetic signal transmitter.

12.- The portable rescue device of claim 11, wherein said array of magnetic vector sensors (S1-SM) include magnetic vector sensors arranged occupying at least one line or at least one plane.

13.- The portable rescue device of claim 12, comprising a main casing (H) housing at least said processing means (UP) and part of said receiving means (Rx), and a support (T; Ta-Tb) onto which at least part of said magnetic vector sensors (S1-SM) are attached, such that they adopt the physical separation with each other which provides said spatial diversity.

14.- The portable rescue device of claim 13, wherein said support is an elongated support which is one of:

- at least one deployable and/or extensible arm (Ta-Tb) connected to said main casing (H) and onto which said magnetic vector sensors (S1-SM) are attached such that they adopt the physical separation with each other which provides said spatial diversity when said at least one deployable and/or extensible arm (Ta-Tb) is at the deployed and/or extended position; or

- a flexible band (T) to be worn by said user in an extended position.

15.- The portable rescue device of any of claims 9 to 14, further comprising electromagnetic transmission means (Tx) and selection means, the latter for alternately:

- activating said electromagnetic receiving means (Rx) for receiving said electromagnetic signal emitted by a portable electromagnetic signal transmitter carried by an avalanche victim, for allowing the user of the portable rescue device (D) act as an avalanche victim locator; or

- activating said electromagnetic transmission means (Tx) for transmitting said electromagnetic signal, for allowing the user of the portable rescue device (D) act as a potential avalanche victim to be located.

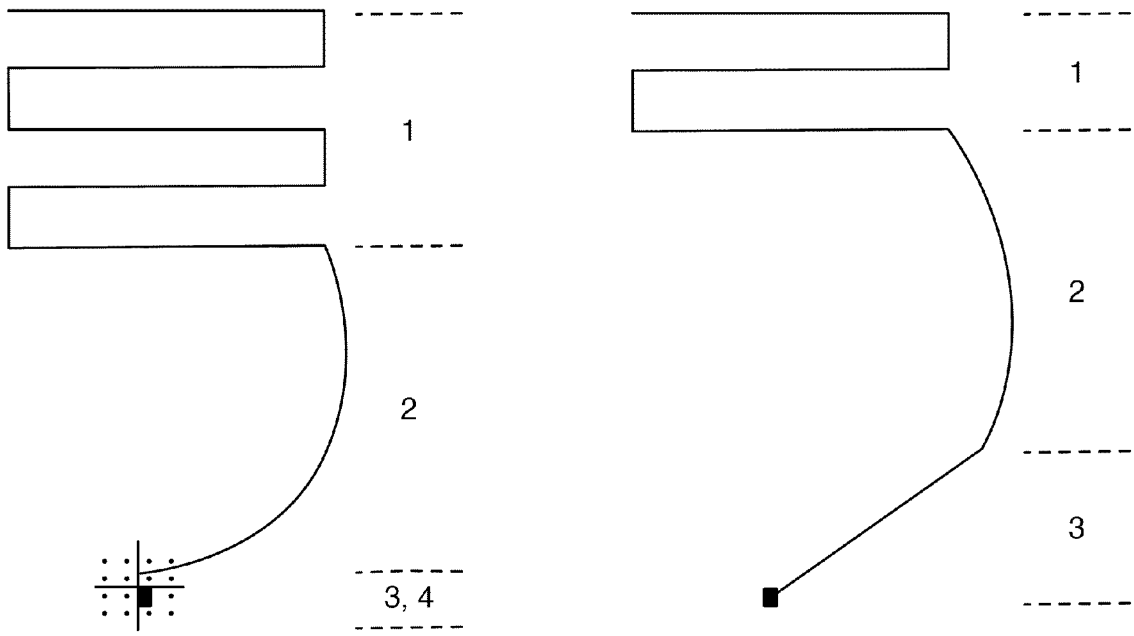

Fig. 1

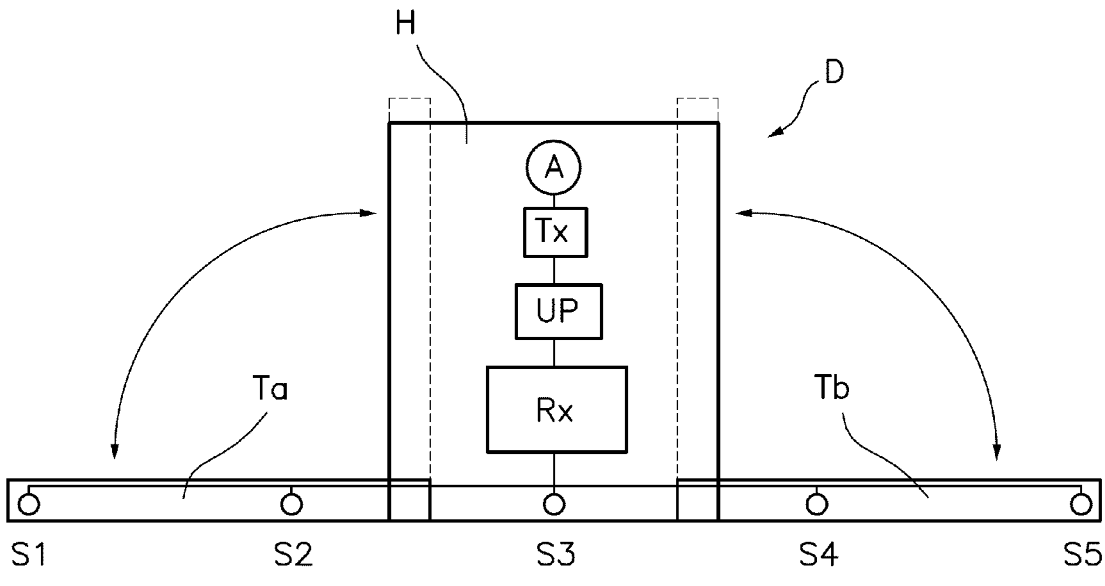

Fig.2

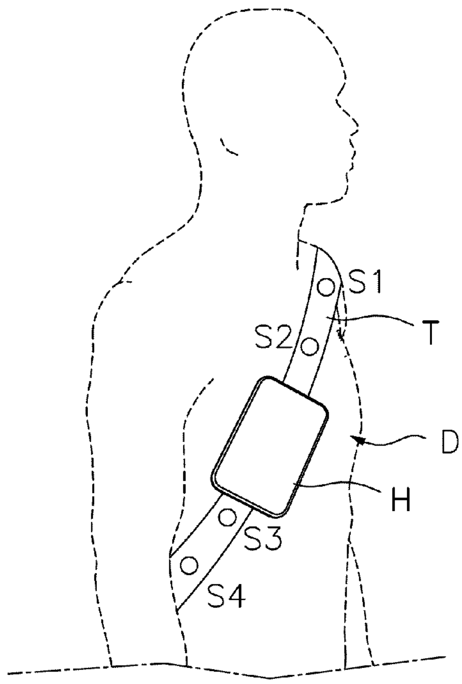
S1
T
S2
D
H
S3
S4

Fig.3

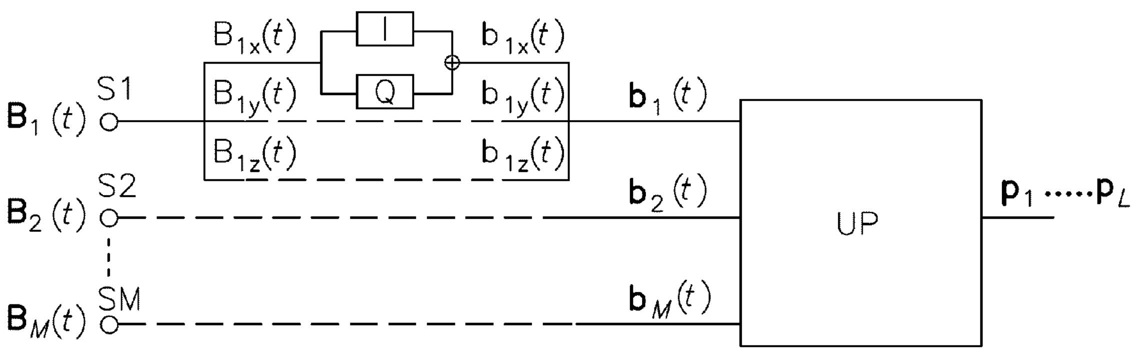
B1x(t)
I
b1x(t)
S1
B1y(t)
Q
b1y(t)
b1 (t)
B1 (t)
B1z(t)
b1z(t)
S2
b2 (t)
p1 .....pL
B2 (t)
UP
SM
bM(t)
BM(t)

Fig.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/069985

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01S3/14 A63B29/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01S A63B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 785 169 A1 (ASCOM SCHWEIZ AG [CH] MAMMUT SPORTS GROUP AG [CH]) 16 May 2007 (2007-05-16) abstract paragraph [0006] - paragraph [0014] paragraph [0050] - paragraph [0052] -----	1,4,5,9
A	US 2011/156957 A1 (WAITE JAMES W [US] ET AL) 30 June 2011 (2011-06-30) abstract; figures 1-10 -----	1,2,9,10
A	EP 1 626 379 A2 (KAMPEL GERALD [DE]) 15 February 2006 (2006-02-15) abstract; figures 9, 10 -----	1,9
A	DE 101 09 284 A1 (KARTHAUS UDO [DE]) 27 March 2003 (2003-03-27) the whole document -----	1,9

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

☒ See patent family annex.

* Special categories of cited documents :

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 November 2014	05/12/2014

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/069985

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			US 2006035622	A1	16-02-2006
DE 10109284	A1	27-03-2003	NONE		