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(54) Title: SYSTEM FOR MEASURING THE WIND SPEED AT A CERTAIN HEIGHT

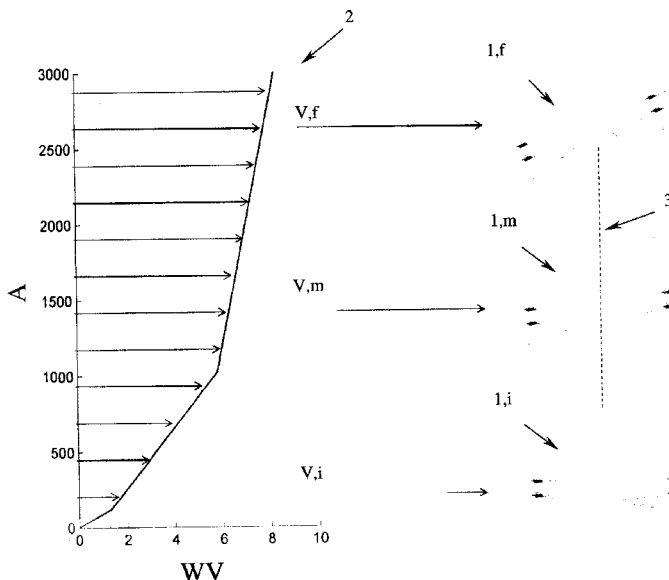


FIG. 4

(57) Abstract: A system is described, for measuring the wind speed at a certain height, comprising at least one unmanned aircraft (1) immersed in a field of motion (2) determined by such wind, such unmanned aircraft (1) being equipped with first on-board processing means adapted to operatively interact on a propulsion system and/or on a flying guiding system of such aircraft (1) to modify its flight attitude depending on external perturbations exerted by such wind present in such field of motion (2) to keep a centring of such aircraft (1) along at least one reference flying trajectory (3) passing through one or more following flight attitudes (1,i, 1,m, 1,f) corresponding with different flight heights above a reference level (S), and detect attitude data related to such attitudes (1,i, 1,m, 1,f) at such relative flight heights.

WO 2014/199405 A1

SYSTEM FOR MEASURING THE WIND SPEED AT A CERTAIN

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HEIGHT

The present invention refers to a system for measuring the wind speed at a certain height.

In particular the invention deals with a
10 system for measuring the wind speed at a certain height to be used as alternative to consolidated measuring systems, such as, for example, the sodar.

The determination of the field of motion around an aircraft immersed in a fluid, is obtained
15 by solving the equations regarding mass preservation, motion amount and energy (Navier-Stokes equations). In aeronautic applications, such approach is possible by adopting the concept of limit layer. According to the Prandtl's limit layer
20 theory, it is possible to identify two different regions in flows with high Reynolds, Re , number. In the first one of these regions, viscous and thermal exchange effects are neglectable and therefore the field of motion is governed with a good
25 approximation by the Euler equations. In the second

region, instead, there are high flow gradients and relevant viscous effects. In such region, the fluid speed increases from a null value on the ground, on which the adherence condition is valid, to the value corresponding to a non-viscous external flow.

In particular, WO2008108894 discloses an array of single sound transducers for a sodar system, in which every transducer emits a sound in the atmosphere by perceiving its sound reflected by the atmosphere itself.

US3937078 instead discloses an apparatus for detecting the orientation of an inclination meter along both directions and in amplitude, in order to determine speed and direction of water currents through a body having a magnetic North and comprising a ball free of oscillating inside a container.

Moreover, EP2390670 discloses a method for estimating the wind speed during the operation of an unmanned aircraft. The wind speed is estimated through the comparison between an acceleration value of the unmanned aircraft and the actual acceleration value determined with one or more sensors.

Object of the present invention is solving the

above prior art problems, by providing a system for measuring the wind speed at a certain height by using an unmanned aircraft and in particular for defining a profile of wind speed at a certain height, of the type which can be activated during the operation of such unmanned aircraft, able to keep a centring on a reference flying trajectory, during the vertical movement of the aircraft itself, by intervening on the modification of a flight attitude depending on external perturbations next to the ground and next to different heights above the ground.

The above and other objects and advantages of the invention, as will appear from the following description, are obtained by a system as claimed in claim 1. Preferred embodiments and non-trivial variations of the present invention are the subject matter of the dependent claims.

It is intended that all enclosed claims are an integral part of the present description.

It will be immediately obvious that numerous variations and modifications (for example related to shape, sizes, arrangements and parts with equivalent functionality) could be made to what is described, without departing from the scope of the

invention, as appears from the enclosed claims.

The present invention will be better described by some preferred embodiments thereof, provided as a non-limiting example, with reference to the enclosed drawings, in which:

- Figure 1 shows an axonometric view of an unmanned aircraft used in the present invention;
- Figure 2 shows a graph related to a field of motion of the wind composed of high flow gradients and relevant viscous effects;
- Figure 3 shows the unmanned aircraft respectively in two positions centred on a reference flying trajectory;
- Figure 4 shows a graphical representation of the relationship between flight attitude of the unmanned aircraft and wind speed.

With reference to the Figures, it is possible to note that the system according to the present invention comprises at least one unmanned aircraft 1, known as "Unmanned Aerial Vehicle (UAV)", or as "drone", immersed in a field of motion 2 determined by the wind, of the type shown in the graphs of Figures 2 and 4, in which the abscissas include wind speed WV values in m/s and the ordinates include height A values in meters, in which there

are high flow gradients and relevant viscous effects. Preferably, such aircraft 1 is a quadricopter.

As an example, it has been assumed that, in
5 such field of motion 2, the fluid (wind) speed increases from a null value, at a reference level S, such as for example the ground, to a value corresponding to the external non-viscous flow.

Advantageously, the unmanned aircraft 1 is
10 equipped with first on-board processing means adapted to operatively interact on the propulsion system and/or on the flying guiding system of the aircraft 1 itself, in order to modify its flight attitude depending on external perturbations
15 exerted by the wind present in such field of motion 2, in order to keep the centring of such aircraft 1 along at least one flight trajectory 3, preferably substantially vertical with respect to the reference level S, passing through one or more of
20 such following flight attitudes, for example starting from a flight attitude 1,i, next to the reference level S, and passing to one or more following flight attitudes 1,m and 1,f, next to different flight heights above the reference level
25 (as shown, for example, in Figure 3) and detect the

attitude data related to such flight attitudes 1,i,
1,m, 1,f at their related flight heights.

The system according to the present invention
further comprises transmitting means adapted to
5 communicate to such first processing means the
position di such reference flying trajectory 3 in
order to allow centring the aircraft 1 itself when
flying along such trajectory 3 and to define the
distance of the aircraft 1 with respect to the
10 reference level S for measuring such flight height
related to each one of such following flight
attitudes 1,i, 1,m, 1,f. Preferably, such
transmitting means comprise at least one laser
tracking system (not shown) of the eco-goniometer
15 type.

The system according to the present invention
further comprises second processing means adapted
to dynamically filter, for example through an
extended or triplicate Kalman filter, the attitude
20 data related to flight attitudes 1,i, 1,m, 1,f and
the related flight height values of the unmanned
aircraft 1, depending on time, for determining a
time history of a forcing element due to wind
present in such field of motion 2, and establishing
25 a relationship between the speeds V,i, V,m, V,f of

such wind and the respective height related to the attitude data. In particular, it is possible to provide that, as regards errors and oscillations of the unmanned aircraft 1 which can impair the
5 measure performed by the system according to the present invention, it is reproduced in real time by a concurrent model implemented in a physical motor of the second processing means, and oscillations or interrupted or approximate data can be complemented
10 by the statuses of the model which is subjected to the same accelerations in the six degrees of freedom, emulating quantities such as masses, motor or propeller powers, and expected wind, as an algorithm the vector sums of positioning errors,
15 speed and acceleration with stresses due to wind, and return a clean value.

Preferred embodiments of the invention have been described, but obviously they can be subjected to further modifications and variations within the
20 same inventive idea. For example, as possible alternatives, the transmitting means can comprise at least one system di tipo GPS.

Moreover, the system of the present invention could be equipped with at least one system (not
25 shown) for recharging its own supply batteries, for

example of the type with electric energy supply,
and equipped with means for performing the function
of monitoring the charge status of the batteries
themselves.

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CLAIMS

1. System for measuring the wind speed at a certain height comprising at least one unmanned aircraft (1) immersed in a field of motion (2) determined by said wind, said
5 unmanned aircraft (1) being equipped with first on-board processing means adapted to operatively interact on a propulsion system and/or on a flying guiding system of said
10 aircraft (1) to modify its flight attitude depending on external perturbations exerted by said wind present in said field of motion (2) to keep a centring of said aircraft (1) along at least one reference flying trajectory (3),
15 characterized in that said aircraft (1) is adapted to pass through one or more of said following flight attitudes (1,i, 1,m, 1,f) corresponding with different flight heights above a reference level (S) and to detect
20 attitude data related to said flight attitudes (1,i, 1,m, 1,f) at said relative flight heights.
2. System according to the previous claim, characterized in that said reference flying
25 trajectory (3) is substantially vertical with

respect to said reference level (S).

3. System according to claim 1, characterized in that said aircraft (1) is a quadricopter.
4. System according to claim 1, characterized in that it comprises transmitting means adapted to communicate to said first processing means a position of said reference flying trajectory (3) to allow a centring of said aircraft (1) when flying along said trajectory (3) and to define a distance of said aircraft (1) with respect to said reference level (S) for measuring said flight height related to each one of said following flight attitudes (1,i, 1,m, 1,f).
5. System according to the previous claim, characterized in that said transmitting means comprise at least one laser tracking system.
6. System according to the previous claim, characterized in that said laser tracking system is of an eco-goniometer type.
7. System according to claim 4, characterized in that said transmitting means comprise at least one system of the GPS type.
8. System according to any one of the previous claims, characterized in that it comprises

second processing means adapted to dynamically filter said attitude data related to said flight attitudes (1,i, 1,m, 1,f) and related values of said flight heights of said unmanned aircraft (1) depending on the time for determining a time history of a forcing element due to said wind present in said field of motion (2) and establish a relationship between a speed (V,i, V,m, V,f) of said wind present in said field of motion (2) and a respective height related to said attitude data.

9. System according to any one of the previous claims, characterized in that it is further equipped with at least one system for recharging its own supply batteries.

10. System according to claim 9, characterized in that said system for recharging the batteries is of the type with electric energy supply.

11. System according to claim 9 or 10, characterized in that it is further equipped with means for monitoring the charge status of the batteries.

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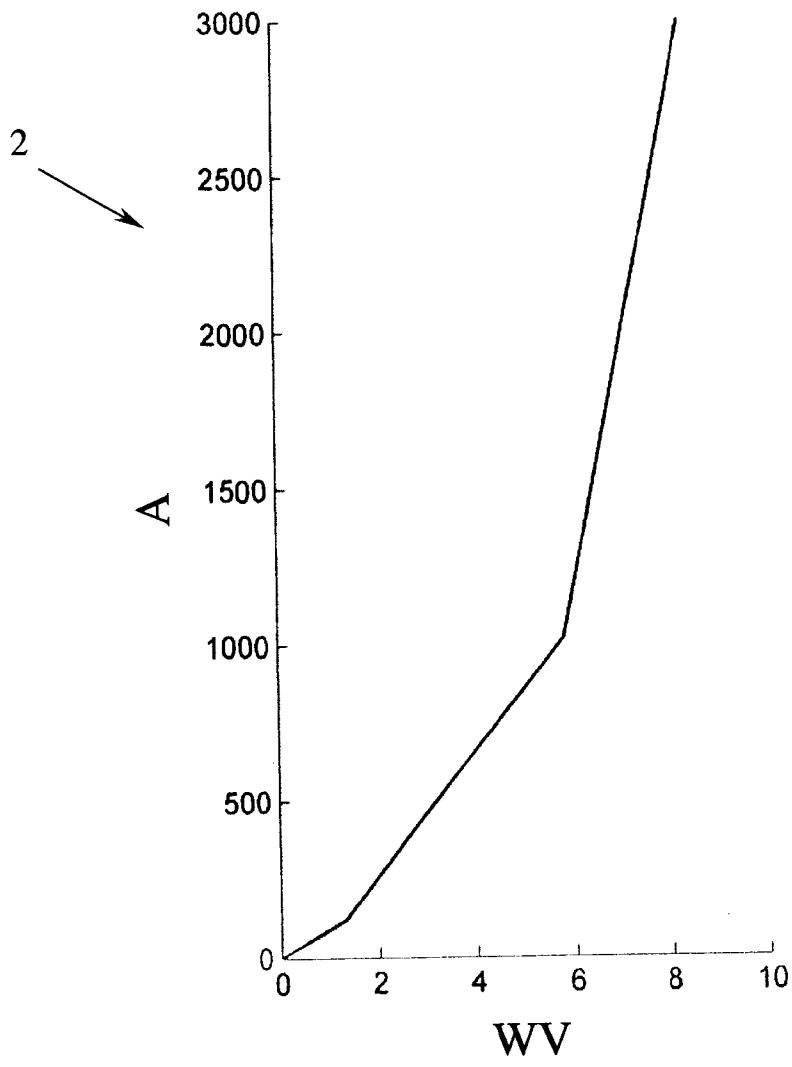


FIG. 2

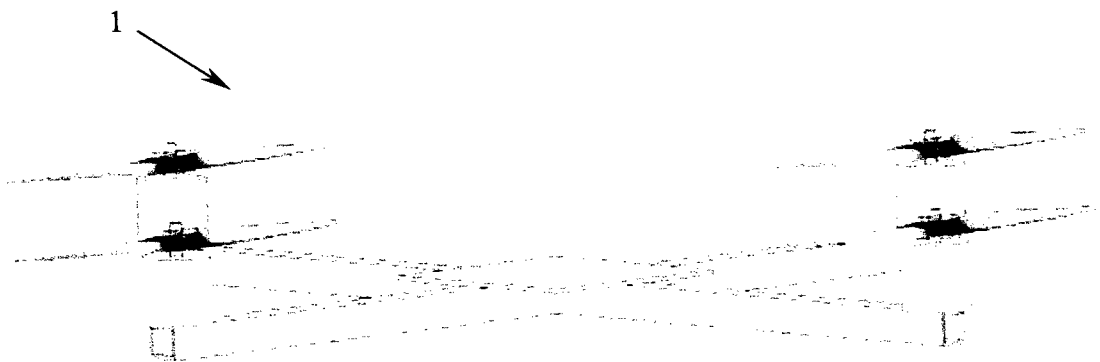
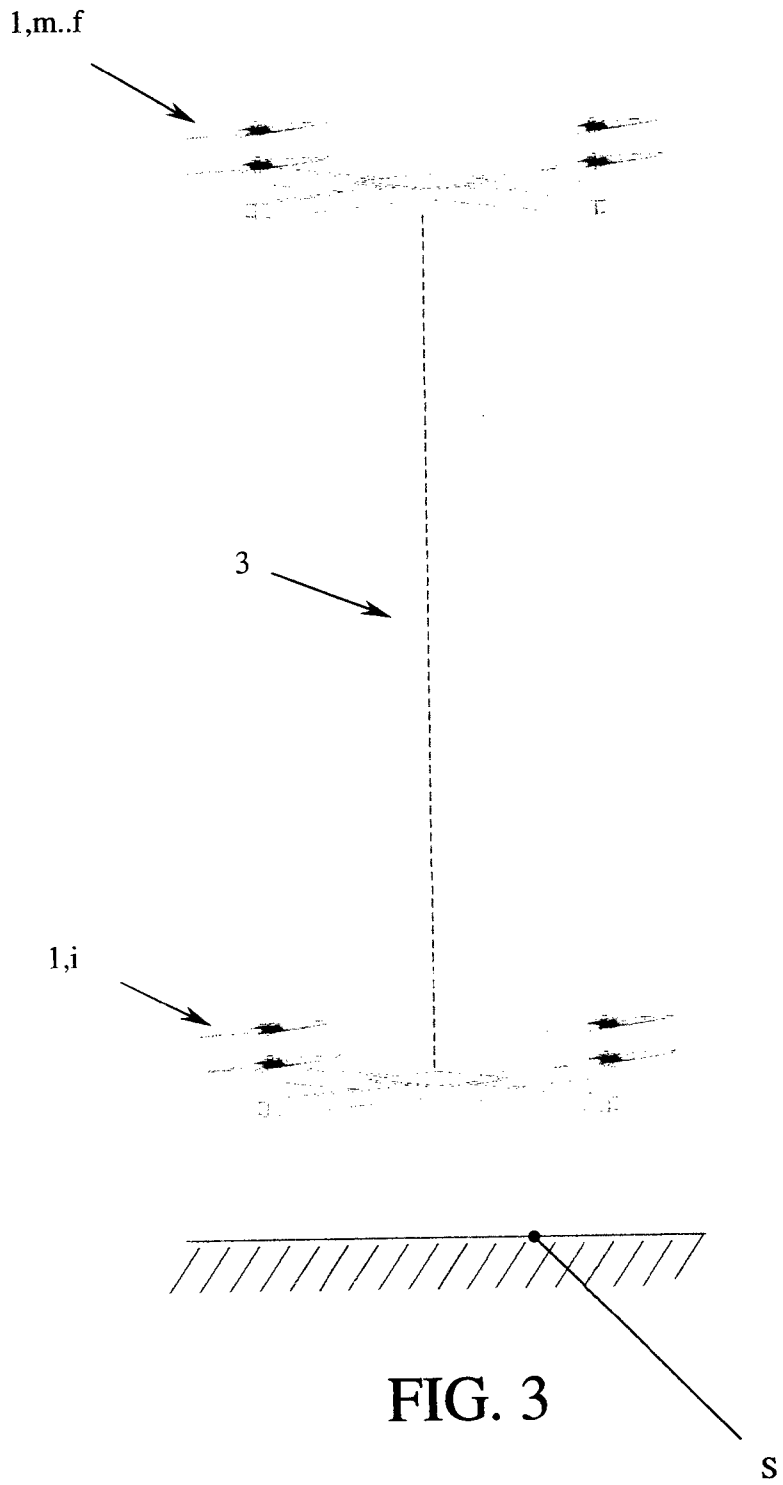


FIG. 1



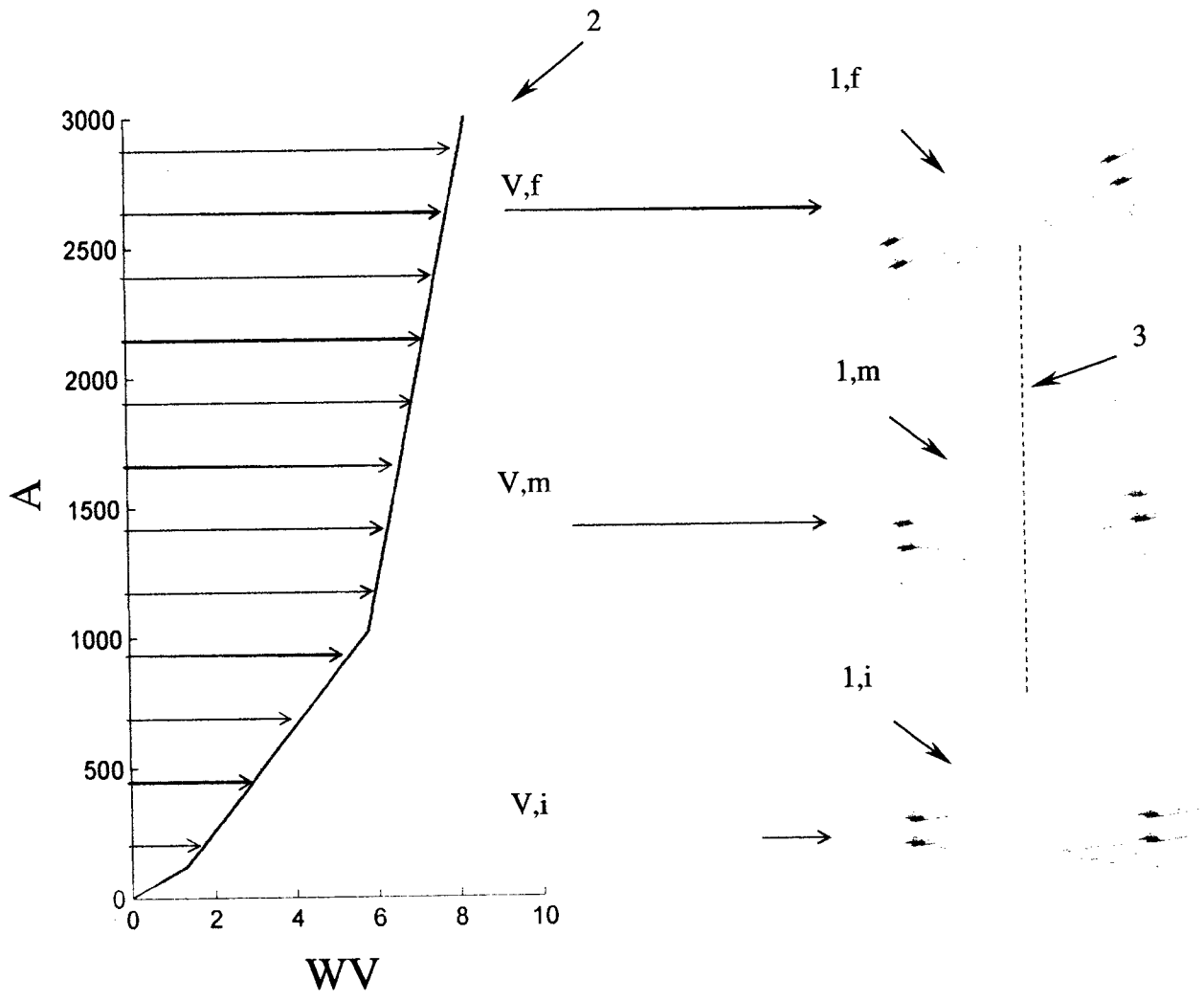


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2014/000129

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01P5/00
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)
G01P

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	ALINE VAN DEN KROONENBERG ET AL: "Measuring the Wind Vector Using the Autonomous Mini Aerial Vehicle M 2 AV", JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY, vol. 25, no. 11, 1 November 2008 (2008-11-01), pages 1969-1982, XP055088980, ISSN: 0739-0572, DOI: 10.1175/2008JTECHA1114.1	1,2,4-11
Y	abstract page 1971, column 1, paragraph 2 page 1970, column 2, paragraph 2 - page 1971, column 1, paragraph 1 page 1974, column 1, paragraph 1 ----- -/--	3

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search 4 September 2014	Date of mailing of the international search report 16/09/2014
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Rabenstein, Winfried
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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 249 848 A1 (DEUTSCHE FORSCH LUFT RAUMFAHRT [DE]) 23 December 1987 (1987-12-23)	3
A	page 3, line 1 - line 15 column 4, line 36 - line 45 -----	1
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/IT2014/000129

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