(12) PATENT (11) Application No. AU 200130022 B2
(19) AUSTRALIAN PATENT OFFICE (10) Patent No. 769332

(54) Title
Mobile system and method for characterizing radiation fields outdoors in an extensive and precise manner

(51)[7] International Patent Classification(s)
G01R 029/10

(21) Application No: **200130022** (22) Application Date: **2000.12.29**

(87) WIPO No: **WO01/50145**

(30) Priority Data

(31) Number	(32) Date	(33) Country
19963794	**1999.12.30**	**DE**
10043461	**2000.09.04**	**DE**

(43) Publication Date : **2001.07.16**
(43) Publication Journal Date : **2001.09.27**
(44) Accepted Journal Date : **2004.01.22**

(71) Applicant(s)
Astrium GmbH

(72) Inventor(s)
Torsten Fritzel

(74) Agent/Attorney
Collison and Co,GPO Box 2556,ADELAIDE SA 5001

(56) Related Art
(SEE INTERNATIONAL SEARCH REPORT)

AU 200130022

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
12. Juli 2001 (12.07.2001)

PCT

(10) Internationale Veröffentlichungsnummer
WO 01/50145 A3

(51) Internationale Patentklassifikation⁷: G01R 29/10

(21) Internationales Aktenzeichen: PCT/DE00/04681

(22) Internationales Anmeldedatum: 29. Dezember 2000 (29.12.2000)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität:
199 63 794.6 30. Dezember 1999 (30.12.1999) DE
100 43 461.4 4. September 2000 (04.09.2000) DE

(71) Astrium GmbH, 81663 Munchen, Germany

~~(71) Anmelder und~~
~~(72)~~ Erfinder: ~~FRITZEL, Torsten~~ [DE/DE]; ~~Wasenöschstr. 59, 88048 Friedrichshafen~~ (DE). ~~Schillerstr. 30 A 85521 Ottobrunn Astrium GMBH 81663~~ ~~Astrium,~~ ~~Munchen~~ ~~Germany~~

(74) Anwälte: SONNENBERG, Fred usw.; Sonnenberg Fortmann, Herzogspitalstr. 10a, 80331 München (DE).

(72) FRITZEL, Torsten; Schillerstr. 30A, D-85521, Ottobrunn (DE)

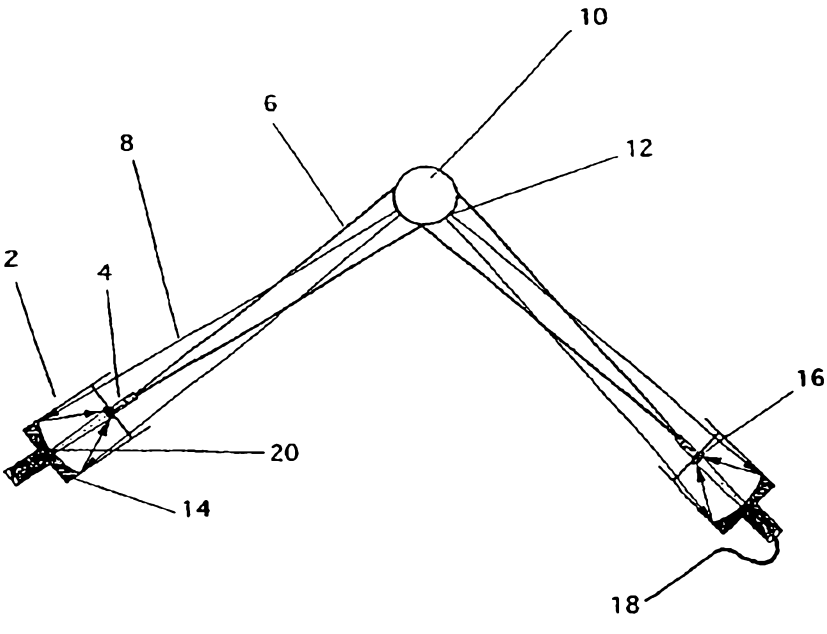
(81) Bestimmungsstaaten *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Bestimmungsstaaten *(regional)*: ARIPO-Patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW).

[Fortsetzung auf der nächsten Seite]

(54) Title: MOBILE SYSTEM AND METHOD FOR CHARACTERIZING RADIATION FIELDS OUTDOORS IN AN EXTENSIVE AND PRECISE MANNER

(54) Bezeichnung: MOBILE ANORDNUNG UND VERFAHREN ZUR GROSSFLÄCHIGEN UND GENAUEN CHARAKTERISIERUNG VON STRAHLUNGSFELDERN IM AUSSENBEREICH



(57) Abstract: The invention relates to a mobile measuring system for characterizing radiation fields, preferably outdoors, in an extensive and highly precise manner. The inventive mobile measuring system is characterized in that a floating and remote controllable platform is provided which measures and characterizes radiation fields in an extensive and highly precise manner using a measuring probe as well as at least one position receiver/antenna.

WO 01/50145 A3

[Fortsetzung auf der nächsten Seite]

eurasisches Patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI-Patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Veröffentlicht:

— *mit internationalem Recherchenbericht*

(88) Veröffentlichungsdatum des internationalen Recherchenberichts: 14. Februar 2002

Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

(57) Zusammenfassung: Vorgesehen ist eine mobile Messanordnung zur grossflächigen und hochgenauen Charakterisierung von Strahlungsfeldern vorzugsweise im Aussenbereich, die sich nach Massgabe der Erfindung dadurch auszeichnet, dass eine schwebende und fernsteuerbare Plattform vorgesehen ist, der mittels einer Messsonde sowie mit zumindest einem Positionsempfänger/-antenne, Strahlungsfelder hochgenau und grossflächig vermisst und charakterisiert.

MOBILE ARRANGEMENT AND METHOD FOR THE LARGE-SURFACE AND ACCURATE CHARACTERIZATION OF RADIATION FIELDS IN THE EXTERIOR REGION

The present invention relates to an arrangement and a method for the highly accurate characterization of radiation fields, as described by the independent claims.

The characterization of radiation fields is indispensable in many areas, as, for example, in the antenna near-field measuring technology. The near-field measuring technique is preferably used in the case of antennas in the frequency range from approximately 0.5 to maximally 20 GHz. In the case of this measuring method, the immediate electromagnetic near field of an antenna is measured and is converted by means of a near-field (NF) to far-field (FF) transformation into the far field by means of the Fast Fourier Transformation (FFT). The advantage of the measuring of the near field of an antenna consists of the compact dimensions of the required antenna measuring systems which so far had almost exclusively be integrated in stationary measuring chambers.

In contrast to near-field measuring systems, there are also far-field measuring systems. Although, on the basis of their dimensions, these are exterior systems, they are always stationary devices and are considerably more errored as a result of reflections from the environment, terrain formations, buildings, etc.

It is another advantage of the near-field measuring technique is that, as a result of a near-field recording, all far-field sections can be computed, while the once measured far-field sections are fixed and the antenna has to be measured again for additional far-field sections at a later point in time.

Corresponding to the scanning theorem, the near field is scanned in $<\lambda/2$ intervals, in which case the entire electromagnetic radiation emitted by the antenna has to be detected to approximately -45db because the entirety of these measuring points has an influence on each individual computed far-field point.

For measuring omnidirectional antennas, spherical scanners are used as a rule which scan the near field of the antenna to be measured on a spherical surface. In the case of directional antennas, the high-expenditure spherical scanners may be eliminated as long as it is ensured that all radiation fractions up to approximately -45db can be detected on a cylinder surface or on a planar surface. Since directional antennas (parabolic antennas) are mainly used, for example, in telecommunications, the selection in this field usually leads to cylindrical near-field measuring systems or planar systems.

Since, in the NF to FF transformation, in addition to the amplitude values of the individual measuring points, the phase information is also significantly used, a scanner, depending on the type, as ideally as possible, should either be able to scan a spherical surface, a cylinder or a planar surface by means of a measuring probe, because the NF to FF transformation is mathematically based on this ideal case. Error contributions by the scanner of a near-field measuring system should not exceed a deviation of $\lambda/50$ from the ideal contour.

Thus a scanner accuracy to be demanded amounts to 3.0 mm, at f=2.0 GHx and a phase accuracy of $\lambda/50$. As far as ground station antennas with an antenna diameter of, for example, 14 mm are to be measured by means of a planar measuring system, this means that this accuracy has to be met on a surface of at least 20 m x 20 m.

With respect to radar, near-field scanners should be as invisible as possible, which is usually contrary to the mechanical expenditures for such scanners and, as a rule, can be achieved only by corresponding absorber coverings.

In order to obtain a maximum of phase accuracy of the measurement, a data recording of all measuring points should take place as rapidly as possible in order to minimize phase drifts over time as much as possible.

Based on the above-mentioned example with a surface to be scanned of 20 m x 20 m and a measuring point distance of 75 mm, in the case of a distribution of 267 measuring points in the width and 267 measuring points along the height of the antenna, a total of at least 71,289 measuring points are obtained. A rough estimate shows that it would cause unacceptable expenditures to drive to each of the measuring points, so that the measuring has to take place during the drive while passing the measuring position. At a scanning speed of 100 mm/sec., the data recording would therefore require approximately 15 hours.

From Stehle et al., "Reledop: A Full-Scale Antenna Pattern Measurement" L.E.E.E. Trans. On Broadcasting, Volume 34, No. 2, June 1988 (1988/06, Pages 210-220 YP 000054225 New York, US) and also Henß, "Hubschrauber-Messung" NTZ Nachrichtentechnische Zeitschrift, Volume 40, No. 4, April 1987 (1987/04, Pages 258-261, YP-002168218) Berlin, DE), it is known to arrange probes by means of a pilot-controlled helicopter with the interposition of a long trail rope or a telescopic rod in a field to be measured. The use of a real helicopter as well as the interposition of long trail ropes or telescopic rods do not allow any highly accurate measuring and particularly also no highly accurate positioning within the field to be measured.

It is an object of the present invention to provide an arrangement and a method for a highly accurate characterization of radiation fields, by means of which highly accurate and large-surface measurements of radiation fields can be carried out at relatively low expenditures, particularly in the exterior region.

This object is achieved by means of the characteristics of the independent claims, expedient embodiments being described by the characteristics of the dependent subclaims.

A measuring arrangement, particularly a mobile measuring arrangement, for the alignment/position and/or detection of electromagnetic characteristics of devices for/with the emission of radiation fields is provided which, according to the invention, is characterized in that a remote-controllable measuring device is provided which can hover with a measuring probe for the detection of the targeted signal and which has at least one device for the determination of the attitude and position of the measuring device, which can be detected by systems for detecting the attitude and position.

The systems for the determination of the attitude and position are preferably position determination systems available at the site of the emission device, and the devices are position receivers/antennas, the position receiver/antenna or position receivers/antennas being provided in a defined relative position with respect to the hovering device.

In the case of the measuring device according to the present invention, preferably a global, non-terrestrial position determination system, such as the GPS, is used as the position determination system, by means of which positions can be determined with a relatively high accuracy.

Furthermore, it is preferred that the position receiver/antenna of the system for measuring the site, the position and the attitude is arranged on the measuring probe. In order to obtain a conformity, which is as accurate as possible, between the electromagnetic measurement and the position determination or alignment of the emitting device, ——————————

the phase center of the measuring probe should be situated as close as possible to the position receiver/antenna.

Furthermore, the emission device is preferably an antenna and, more specifically, a parabolic antenna or an array antenna.

In addition, the measuring arrangement may be constructed such that the measuring device has a combination of the position receiver/antenna, a compass, a device for measuring the inertia forces, and one or more rotation sensors for determining and controlling the attitude of the hovering device. To the extent that it should be necessary in a special application, other components can naturally be added to the above-mentioned ones.

The measuring arrangement according to the present invention can also be constructed such that the measuring device has a plurality of position receivers/antennas which are arranged on the hovering device in a spatially separated manner, which permits the use of a differential method for determining the position and attitude of the hovering device.

Finally, in the case of the measuring arrangement according to the invention, an additional position receiver/antenna is provided as a reference on the ground in the area of the emission device, which permits the application of a differential method for determining the position and attitude of the hovering device.

In the case of a measuring arrangement constructed in this manner, no direct visual contact is required between a ground station, at which, for example, the measuring equipment for processing the data supplied by the measuring probe as well as devices for controlling the hovering measuring device can be provided, and the receiver, which may be an advantage, particularly in the case of spherical scanning contours.

The arrangement consisting of position receivers/antennas and/or the measuring probe can advantageously be provided on the hovering device in such a manner that an angular adjustment, a swivelling or a stabilization of the measuring probe is possible in order to, for example, also under the effect of wind, ensure a desired alignment independent of an inclined position of the hovering device, such as a helicopter. In particular, a stabilization for small position and angle deflections can be provided which can take into account the relative position of the emission device. This stabilization and/or positioning can advantageously also interact with the measuring control circuit, so that a corresponding tracking can be displayed. As a result, a compensation of tolerances and therefore an acceleration of the individual measurements can be achieved.

As an alternative, the measuring arrangement for the highly accurate alignment/positioning and/or detection of electromagnetic characteristics of devices for the/with the emission of targeted radiation and/or wave-shaped signals may be constructed such that devices are provided on the measuring probe for detecting the signal placed in a hovering manner in front of the emission device, the relative momentary measuring position of these devices being detectable by at least one arrangement for the position measuring by means of a geodetic instrument which is equipped with a device for emitting a defined optical signal as well as with a device for receiving an optical signal, as well as with a device for the reflection of the defined optical signal of the geodetic instrument at the position to be measured, the device for the reflection of the defined optical signal being formed, for example, by a reflecting spherical reflection surface, so that the reflection of the defined optical signal is reduced to a point for the viewer, and (the point? word missing in the German) or the spherical reflection surfaces being provided in a defined relative position with respect to the hovering device and/or the measuring probe.

This measuring arrangement may be constructed such that the reflection surface is part of a metal-coated sphere.

Furthermore, this measuring arrangement is preferably constructed such that the geodetic device for receiving an optical signal is provided with a concave primary mirror, a convex secondary mirror as well as a detector device sensitive in two dimensions, such as a position diode for generating a reading signal. As an alternative to the mirrors, other optical systems, such a reflectors/refractors can also be used.

Also, this measuring arrangement may be constructed such that the secondary mirror is placed essentially in the focus of the primary mirror and the detector device is placed opposite the secondary mirror in the area of the primary mirror, the detector device being preferably placed behind an opening in the primary mirror, through which the reflected optical signal passes which is focussed in the secondary mirror.

Likewise, two geodetic instruments are preferably assigned to each reflection device, so that a cross bearing is permitted.

The optical signal emitted by the geodetic instrument is preferably a laser beam, particularly a power-adjustable and/or modulable laser beam, in which case the geodetic instrument may be provided with highly accurate angle-position encoders in the azimuth and in the elevation, for the dynamically accurate detection of the bearing angles with respect to the respective reflector. For example, when two laser beams are used, these can be modulated with a different frequency so that an identification of the reflected signal is possible. Also, in a particularly preferred embodiment, it is possible to make the power adjusting possibility a function of the distance between the laser source reflector and the detector device, whereby damage to the diode as a result of excessive laser irradiation can be avoided. It was found to be particularly advantageous to use a semiconductor laser as the laser beam, in which case the modulation can be represented as an alternative or in a supporting manner also by frequency filters.

In this case, this measuring arrangement is preferably constructed such that three of the above-mentioned arrangements are provided with three reflection surfaces provided in a defined relative position on the hovering device.

The measuring arrangement itself is capable of detecting electromagnetic characteristics in a manner known per se, normally a measuring probe being used for this purpose. Thus, a reciprocal relationship can be achieved between the electromagnetic measurement, the measuring site and/or the position of the radiating device. As a result of the highly accurate relative determination of the three parameters - position, field and generating of the field -, it is possible in a simple manner to carry out a plurality of highly accurate measurements, in which case the measuring probe can be operated, for example, by using the initially described near-field measuring technique.

Furthermore, one of the spherical reflection surfaces is preferably arranged on the measuring probe. In order to achieve a conformity between the electromechanical measurement and the position determination or alignment of the radiating device which is as exact as possible, the phase center of the measuring probe should be situated as close as possible to the center point of the spherical reflection surface, an optimum of precision being obtained when the center point of the sphere and the phase center coincide. In addition, the emission device preferably is an antenna and, more specifically, a parabolic antenna or an array antenna.

In addition to the above-mentioned characteristics, this measuring arrangement can have the advantage of providing an autofocussing device for the imaging of the reflected laser beam. This promotes the fast detection of individual measuring points and their precision. It should also be mentioned that also the relative position of the diode or the detector device can be evaluated in the display area in order to further increase the measuring accuracy.

The size and the mass of the hovering device in relationship to the emission device to be positioned is preferably selected to be small in this case, because objects in an electromagnetic field to be measured may result in considerable measuring errors. In order to meet this requirement, it is advantageous to provide, for example, a miniature helicopter as a hovering device. However, alternatives, such as controlled balloons, zeppelins, or similar devices, are also conceivable, which preferably are radio-telecontrolled.

In addition to the measuring arrangement, the invention also provides a method for the highly accurate characterization of radiation fields, particularly for the mobile use and/or in the exterior region which comprises the following steps according to the invention:

1. The hovering arrangement of a remote-controllable measuring device in the radiation field, with a measuring probe for the detection of the radiation field as well as with at least one device for determining the attitude and position of the measuring device, which device can be detected by systems for determining the attitude and position;

2. the determination of the position and attitude of the measuring device; and

3. the generating of a measuring signal for characterizing the radiation field;

4. the transmission of the measuring signal from the hovering part of the measuring arrangement to the ground-side measuring instrument system.

According to the invention, the method can be further developed such that the coordinates of the systems (mistake in the German? This should probably be "the coordinates of the device for determining the attitude and position of the measuring device, which can be detected by systems for determining the attitude and position,) can be determined in three space dimensions, and from these coordinates, the actual position and the actual attitude of all six degrees of freedom of the measuring device is dynamically determined particularly in real time.

Furthermore, the actual position and the actual attitude of all six degrees of freedom of the measuring device can be compared with the defined desired position and desired attitude and can be controlled in a closed-loop control circuit by means of the control of the measuring device, during the controlling, the stabilization or positioning of the measuring probe being used.

Finally, a person skilled in the art will understand that, although the present application addresses a radiating device, the invention can naturally also be used in a reversal/supplementation in the case of a receiving system or a field-alternating, particularly a reflecting device.

The decisive advantages of measuring arrangements or systems constructed according to the invention are that, as a result of their mobility, they permit a complete characterization of radiation characteristics of large, usually stationary antenna systems in the exterior region at all and, in addition, do so in a highly accurate manner.

Additional advantages of the solution according to the invention are among others,

- a high positioning precision from approximately 2.0 mm to 50 m
- large positioning ranges of up to 100 m edge length of a cube
- high positioning speed <1.0 min over a positioning route of 100 m
- highly accurate detection of all 6 degrees of freedom of 0.5 mm and 1.0 angular minutes at a distance of 50 m
- mobility
- lower installation expenditures
- broad application spectrum (antenna measurements, radar backscattering measurements, electromagnetic compatibility measurements, environmental measurements, etc.)

Additional characteristics and advantages of the invention are found in the following description of preferred embodiments of the invention with respect to the attached drawings.

Figure 1 is a schematic representation of an embodiment of a geodetic instrument for position measuring;

Figure 2 is a schematic lateral view of an embodiment of the measuring arrangement for the positioning by means of geodetic instruments;

Figures 3 to 5 are views of an embodiment of the hovering device;

Figure 6 is a top view of the measuring arrangement according to Figure 2;

Figure 7 is a frontal view of the measuring arrangement according to Figure 2;

Figure 8 is a schematic representation of the regulating and control concept;

Figure 9 is a schematic lateral view of an embodiment of the measuring arrangement for the positioning by means of position determination systems;

Figure 10 is a top view of the measuring arrangement according to Figure 9;

Figure 11 is a frontal view of the measuring arrangement according to Figure 9.

Figure 1 illustrates an embodiment of an arrangement for the position measuring, having two geodetic instruments 2, here optical theodolites, which are each provided with a device 4 for emitting a defined optical signal 6, here a laser beam, as well as a device for receiving an optical signal 8, as well as with a device 10 for the reflection of the defined optical signal 6 of the geodetic instrument 2 at the position to be measured, the device 10 for the reflection of the defined optical signal 6 is formed here by a reflecting or metal-coated sphere 10 so that the reflection of the defined optical signal 6 is reduced to a point 12 for the viewer.

As further illustrated in Figure 1, the geodetic device 2 for receiving the reflected optical signal 8 is equipped with a concave primary mirror 14, a concave secondary mirror 16 as well as a detector device 18 sensitive in two dimensions for generating a reading signal. In this case, the secondary mirror 16 is arranged in the focus of the primary mirror 14, the detector device 18 being placed opposite the secondary mirror 16 in the area of the primary mirror 14 behind an opening 20 in the primary mirror, through which opening 20 the reflected optical signal 8 passes which is focussed in the secondary mirror 16. In the illustrated embodiment, the geodetic instrument 2 is equipped with highly accurate angle-position encoders and tracking drives in the azimuth and the elevation, for the dynamically accurate detection/tracking of the bearing angles to the respective reflector, by means of the detector device 18.

Figure 2 shows the embodiment of a measuring arrangement for the highly accurate alignment/positioning of a device for the emission of targeted radiation-type and/or wave-shaped signals, here, a parabolic antenna 22, in the measuring arrangement of the illustrated embodiment, a device 24 being provided which is equipped with a measuring probe for detecting the signal of the antennas 22 and hovers in front of the measuring probe. The position of this device 24 can be detected by a number of arrangements for the position measuring, as illustrated in Figure 1. Figure 2 shows six optical theodolites 2, the laser beams 6 originating from the latter being aimed at reflectors fastened to the device 24 hovering in front of the antenna 22.

Figures 3 to 5 are more detailed views of the hovering device 24 of the embodiment according to Figure 2. Here it is illustrated that a preferably miniaturized helicopter is used which is provided with three devices 10 for the determination of the attitude and position of the measuring device 24, which devices 10 can be detected by systems for determining the attitude and position. These devices 10 are fastened to extension arms 26 or to the measuring probe 28 for the detection of the antenna signal in a defined position with respect to the helicopter. These devices may, for example, be metal-coated spheres 10, as described with reference to Figure 1, or position receivers/antennas 10 for position determination systems (not shown) available at the site of the emission device 22.

The miniature helicopter is used in the illustrated embodiment because it is suitable for taking up a stable hovering position in front of the antenna 22 to be measured, has a small mass in comparison to the latter, so that virtually no measuring errors have to be expected as a result of the helicopter, and can be controlled by means of a simple technology which is available at any time. In order to further reduce measuring errors, a positioning and/or stabilizing device, which is not shown, can be provided which represents a certain uncoupling with respect to the helicopter and permits an almost arbitrary position of the latter with respect to the radiating device. When the helicopter is, for example, present above the radiating device, the measuring probe should be essentially directed downward.

Figures 6 and 7 are a top view and a frontal view respectively of the embodiment of Figure 2, identical elements having the same reference numbers.

The measuring arrangement according to Figures 2 to 7 operates such that the positions of the laser reflectors 10, which are fastened to the helicopter, are each determined by means of two of the highly accurate angle measuring devices 2 in the azimuth and in the elevation. In this case, an automatic target tracking takes place based on the laser beam 6 emitted by the respective angle measuring device or optical theodolite 2, for example, by means of a tracking device.

When several laser beams are used, it should be possible to differentiate these from one another. For this purpose, modulable semiconductor lasers or lasers which frequency filters connected on the output side can, for example, be used, so that each laser beam has separate specific characteristics which permit its identification.

This laser beam 6 is reflected at one of the laser reflectors 10 mounted on the helicopter and is imaged by the optical telescope 14, 16 situated in the respective angle measuring device 2 on the detector device 18 sensitive in two dimensions. As a result of a movement of the helicopter and thus of the laser reflectors 10, a course indicating signal is generated and is fed into a regulating circuit which causes a tracking by means of tracking drives, which are not shown, in the azimuth and in the elevation. Highly accurate angle-position encoders in the azimuth and in the elevation (not shown) supply in a dynamically precise manner the bearing angles to the respective laser reflector 10. Since, as illustrated in Figures 2, 6 and 7, two angle measuring devices

2 respectively 2 take a bearing with respect to the same laser reflector 10, the coordinates of the respective laser reflector 10 can be determined in three space dimensions. From the coordinates of the three laser reflectors 10, the actual position and the actual attitude of all six degrees of freedom of the helicopter 24 will then be dynamically determined. This information is compared with the given desired position and desired attitude and is controlled in a closed-loop control circuit by means of the helicopter control. By means of this method, the helicopter or the measuring probe 28 mounted thereto for detecting the targeted signal of the antenna 22 can be positioned with the highest precision in all 6 degrees of freedom at heights of up to 100 m. The downlink from the helicopter 24 as the hovering device takes place according to known transmission concepts, in which case the coupling by way of a glass fiber arrangement freed of expansion faults is preferred in addition to other possibilities. However, care should be taken that this results in no faults, such as a phase displacement.

Figure 8 illustrates the regulating and control concept of the present invention. The angle measuring devices 2 are connected with position computers 30 which compute the respective position of a reflector 10 in real time. The position data determined in this manner are transmitted to the position and attitude computer 32 of the hovering device 24. The actual values for the position and the attitude are fed into point 34, whereupon, at reference number 36, a desired/actual comparison takes place with respect to the position and attitude taking into account the desired values 38 for the position and attitude originating from the application, and, on the basis of this comparison, correcting variables for the helicopter control 40 are generated which are transmitted by way of a remote control 42 to the helicopter 24.

Figure 9 shows another embodiment of a measuring arrangement for the highly accurate characterization of radiation fields. The same elements as in Figures 1 to 8 have the same reference numbers. In the case of the measuring arrangement of the illustrated embodiment, a remote-controllable hoverable measuring device 24 is also provided which is equipped with a measuring probe 28 for detecting the targeted signal as well as with at least one position receiver/antenna 10 for position determination systems (not shown) available at the site of the emission device 22. In the case of the measuring arrangement according to the present invention, a global non-terrestrial site determination system, such as the GPS, is preferably used as the position determination system, by means of which positions above the earth surface can be determined with a relatively high accuracy. Another stationary position receiver/antenna 44 is provided at a ground station. The measuring device 24 is connected by way of a data link 42 with a ground station or the position receiver/antenna 44 provided there, which supplies a highly accurate reference position.

By means of the measuring arrangement, a reciprocal relationship can be achieved between the electromagnetic measurement, the measuring site and/or the position of the radiating device 22. As a result of the highly accurate relative determination of the three parameters - position, field and generating of fields -, it is possible in a simple manner to implement a plurality of highly accurate measurements, in which case, the measuring probe 28 can be operated, for example, by using the near-field measuring technique.

It should be noted in this case that here the preferably miniaturized helicopter, as described with reference to Figures 3 to 5, is equipped with three position receivers/antennas 10 for a navigation or positioning system, such as the GPS, which are fastened to the extension arms 26 or to the measuring probe 28 in a defined position to the helicopter and to one another respectively. In order to obtain a conformity between the electromagnetic measurement and the position determination or alignment of the radiating device 22 which is as exact as possible, the phase center of the measuring probe 28 is situated very close to a position receiver/antenna 10.

By providing a plurality of position receivers/antennas 10, which are arranged in a spatially mutually separated manner at the miniature helicopter 24, as well as the additional position receiver/antenna as reference on the ground in the area of the emission device, the use of a different method for the position and attitude determination, such as the DGPS of the helicopter 24 is permitted.

In the case of a measuring arrangement constructed according to the present invention, no direct visual contact is required between the ground station 44, at which, for example, measuring equipment may be provided for the processing of the data supplied by the measuring probe as well as devices for controlling the hovering measuring device 24, and the respective receiver 10, which may be an advantage, particularly in the case of spherical scanning contours.

In order to further reduce measuring errors, a positioning and/or stabilizing device, which is not shown, can be provided which represents a certain uncoupling with respect to the helicopter and permits an almost arbitrary position of the latter with respect to the radiating device. When the helicopter is, for example, present above the radiating device, the measuring probe 28 should be essentially directed downward.

Figures 10 and 11 are a top view and a frontal view respectively of the arrangement of Figure 9.

The measuring arrangement according to Figures 9 to 11 operates such that the positions of the position receiver/antenna 10, which are fastened to the helicopter 24, as well as of the position receiver/antenna 44 of the ground station 44 are determined in each case, from which the respective momentary position and attitude of the helicopter 24 can be computed preferably in real time.

By the use of a corresponding navigation or positioning system, such as the GPS, the coordinates of the respective position receiver/antennas 10 can be determined. From the coordinates of the three position receivers/antennas 10 as well as the position receiver/antenna 44, the actual position and the actual attitude of all six degrees of freedom of the helicopter 24 will then be dynamically determined. This information is compared with the defined desired position and desired attitude and is controlled in a closed-loop control circuit by means of the helicopter control. By means of this method, the helicopter or the measuring probe 28 mounted thereon for detecting the targeted signal of the antenna 22 can be positioned in all 6 degrees of freedom with the greatest accuracy. The downlink 42 from the helicopter 24 as a hovering device takes place according to known concepts, in which case the transmission of the measuring signals for the characterization of the radiation field can be implemented, for example, by means of a glass fiber arrangement from which the expansion and temperature errors have been removed. Care should, however, be taken that no inadmissible errors, such has phase displacements, occur as a result.

The regulating and control concept of the present invention provides that position computers compute the respective position of a position receiver/antenna 10 as much as possible in real time. The position data determined in this manner are transmitted to a position computer of the helicopter 24. The actual values for the position and attitude are fed into the position computer of the helicopter 24, whereupon a desired/actual comparison takes place with respect to the position and attitude while the desired values for the position and attitude are taken into account which originate from the application, and on the basis of this comparison, operating variables for the helicopter control are generated which are transmitted by remote control to the helicopter 24.

By means of the arrangement according to the present invention, a high positioning accuracy can be achieved in a simple and advantageous manner, simultaneously high positioning speeds and a highly accurate detection of all 6 degrees of freedom and mainly a highly accurate characterization of radiation fields being permitted. In this case, the arrangement and the method are suitable for applications in the exterior region, ensure mobility, require low installation expenditures and have a broad application spectrum (antenna measurements, radar backscattering measurement, electromagnetic compatibility measurements, environmental measurements, etc.) However, on the basis of their mobility, they mainly permit a highly accurate and large-surface measuring and characterization of radiation fields in the exterior region.

In addition to the illustrated embodiment, a combination of individual elements of the respective embodiments with one another is naturally also conceivable.

CLAIMS:

1. Measuring arrangement for aligning/positioning and/or detecting the electromagnetic characteristics of devices (22) for the/with the emission of radiation fields, characterized in that a remote-controllable measuring device (24) is provided which can hover with a measuring probe (28) for the detection of the targeted signal and which has at least one device (10) for the determination of the attitude and position of the measuring device (24), which device (10) can be detected by systems for detecting the attitude and position, the size and the mass of the measuring device (24) being selected to be small in relation to the emission device (22) to be positioned.

2. Measuring arrangement according to Claim 1, characterized in that the systems for the determination of the attitude and position are position determination systems available at the site of the emission device (22), and the devices (10) are position receivers/antennas, the position receiver/antenna or position receivers/antennas (10) being provided in a defined relative position with respect to the hovering device (24).

3. Measuring arrangement according to Claim 2, characterized in that a global non-terrestrial site determination

system is used as the position determination system.

4. Measuring arrangement according to one of Claims 1 to 3,
characterized in that a position receiver/antenna (10) is arranged on the measuring probe (28).

5. Measuring arrangement according to Claim 4,
characterized in that the position receiver/antenna (10) is arranged in the direct proximity of the phase center of the measuring probe (28).

6. Measuring arrangement according to one of Claims 2 to 5,
characterized in that the measuring device (24) has a combination of the position receiver/antenna (10), a compass, a device for measuring the inertial forces and/or accelerations, and one or more rotation sensors for the determination and control of the attitude of the hovering measuring device (24).

7. Measuring arrangement according to one of Claims 2 to 6,
characterized in that the measuring device ((24) has a plurality of position receivers/antennas (10) which are arranged on the hovering device in a spatially mutually separated manner.

8. Measuring arrangement according to one of Claims 1 to 7, characterized in that an additional position receiver/antenna

(44) is provided as a reference on the ground in the area of the emission device (22).

9. Measuring arrangement according to Claim 1, characterized in that the systems for determining the attitude and position are at least one geodetic instrument (2) which is equipped with a device (4) for emitting a defined optical signal (6) as well as with a device for receiving an optical signal (8), and the devices (10, 2) are at least one reflecting spherical reflection surface (10) for the reflection of the defined optical signal (6) of the geodetic instrument (2) at the position to be measured, so that the reflection of the defined optical signal is reduced to a point (12) for a viewer, the spherical reflection surfaces (10) being provided in a defined relative position with respect to the hovering device (24).

10. Measuring arrangement according to Claim 9, characterized in that the reflection surface is part of a metal-coated sphere (10).

11. Measuring arrangement according to one of Claims 9 to 10, characterized in that the device for receiving an optical signal is provided with a concave primary mirror (14), a convex secondary mirror (16) as well as a detector device sensitive in

two dimensions, such as a position diode (18), for generating a reading signal.

12. Measuring arrangement according to one of Claims 9 to 11,
characterized in that the secondary mirror (16) is placed essentially in the focus of the primary mirror (14) and the detector device (18) is placed opposite the secondary mirror (16) in the area of the primary mirror (14).

13. Measuring arrangement according to Claim 12, characterized in that the detector device (18) is placed behind an opening (20) in the primary mirror (14).

14. Measuring arrangement according to one of Claim 9 to 13,
characterized in that two geodetic instruments (2) are assigned to each reflection device (10), so that a cross bearing is permitted.

15. Measuring arrangement according to one of Claims 9 to 14,
characterized in that the optical signal emitted by the geodetic instrument (2) is a laser beam (6), particularly a power-adjustable and/or modulable laser beam (6).

16. Measuring arrangement according to one of Claims 9 to 15,

characterized in that the geodetic instrument (2) is equipped with highly accurate angle-position encoders in the azimuth and in the elevation, for the dynamically accurate detection of the bearing angles with respect to the respective reflector (10).

17. Measuring arrangement according to one of Claims 9 to 16,

characterized in that three reflecting, spherical reflection surfaces (10) are provided for the reflection of the defined optical signal (6) of the geodetic instrument (2) at the position tc be measured.

18. Measuring arrangement according to one of Claims 9 to 17,

characterized in that one of the spherical reflection surfaces (10) is arranged on the measuring probe (28), the phase center of the probe essentially coinciding with the center point of the spherical reflection surface.

19. Measuring arrangement according to one of the preceding claims,

characterized in that the measuring probe (28) is constructed for use in the near-field measuring technique.

20. Measuring arrangement according to one of the preceding claims, characterized in that the measuring device (24) is a remote-controlled miniature helicopter.

21. Measuring arrangement according to one of Claims 1 to 19, characterized in that the measuring device (24) is a remote-controlled balloon.

22. Measuring arrangement according to one of Claims 1 to 19, characterized in that the measuring device (24) is a remote-controlled zeppelin.

23. Measuring arrangement according to one of Claims 1 to 19, characterized in that the measuring device (24) is remote-controlled airplane.

24. A method for the highly accurate characterization of radiation fields including the steps of providing a remote controllable measuring device which can hover including a measuring probe adapted for the detection of a radiation field further including at least one device for determining the attitude and position of the measuring device, which device can be detected by systems for determining the attitude and position;
determining the position and attitude of the measuring device;
generating a measuring signal for characterizing the radiation field;
transmission of a measuring signal from the hovering part of the measuring arrangement to a ground site measuring instrument system.

25. Method according to Claim 24, characterized in that the coordinates of the respective position receiver/antenna (10, 2) are determined and, from these coordinates, the actual position and the actual attitude of all six degrees of freedom of the measuring device is dynamically determined, particularly in real time.

26. Method according to Claim 24 or 25, characterized in that the actual position and the actual attitude of all six degrees of freedom of the measuring device (24) are compared with a defined desired position and desired attitude and are controlled in a closed-loop control circuit by means of the control of the measuring device (24).

Dated this 18 day of November 2003

ASTRIUM GMBH
By their Patent Attorneys
COLLISON & CO

Fig. 1

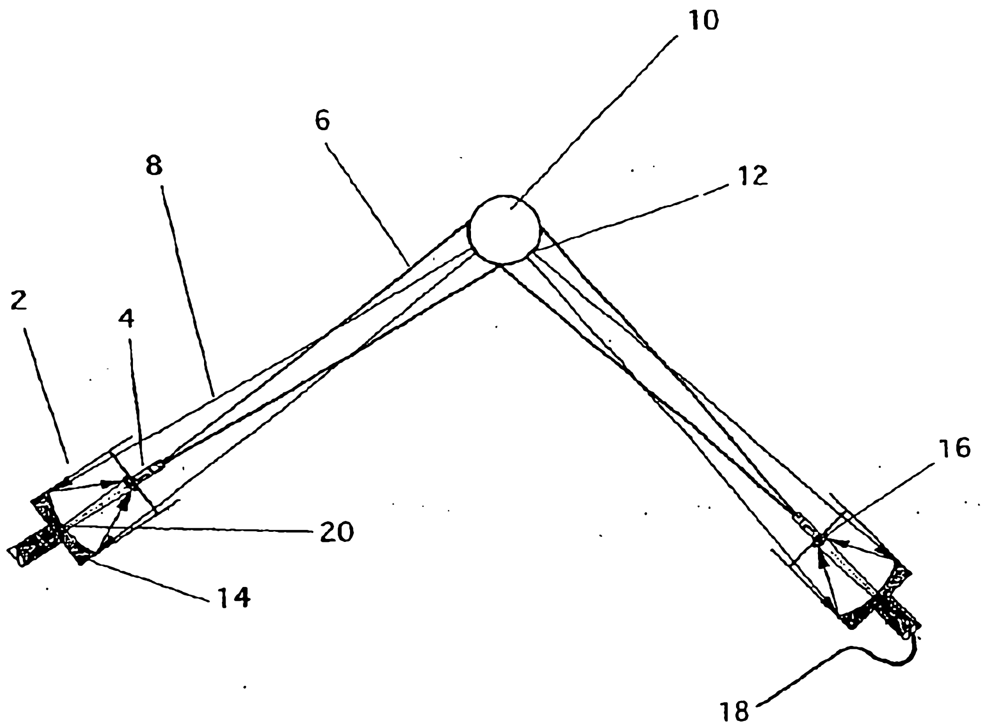


Fig. 2

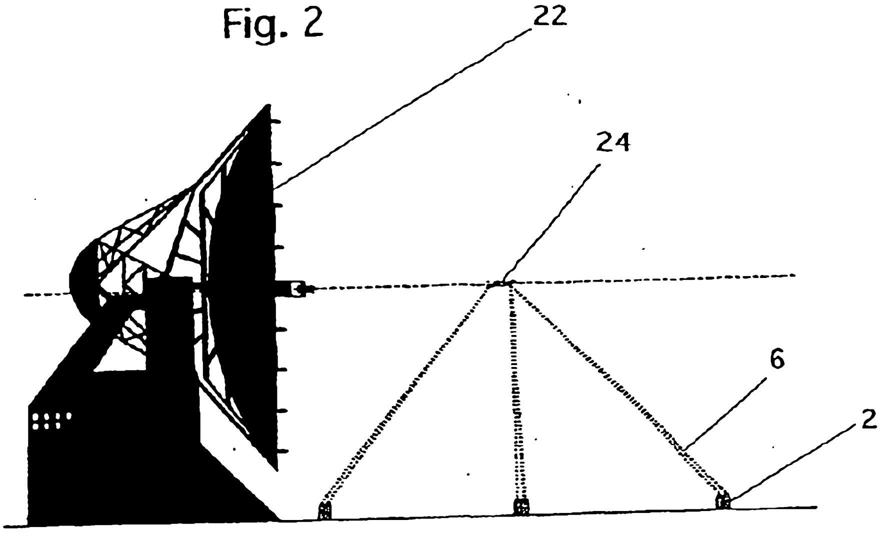


Fig. 3 Fig. 4

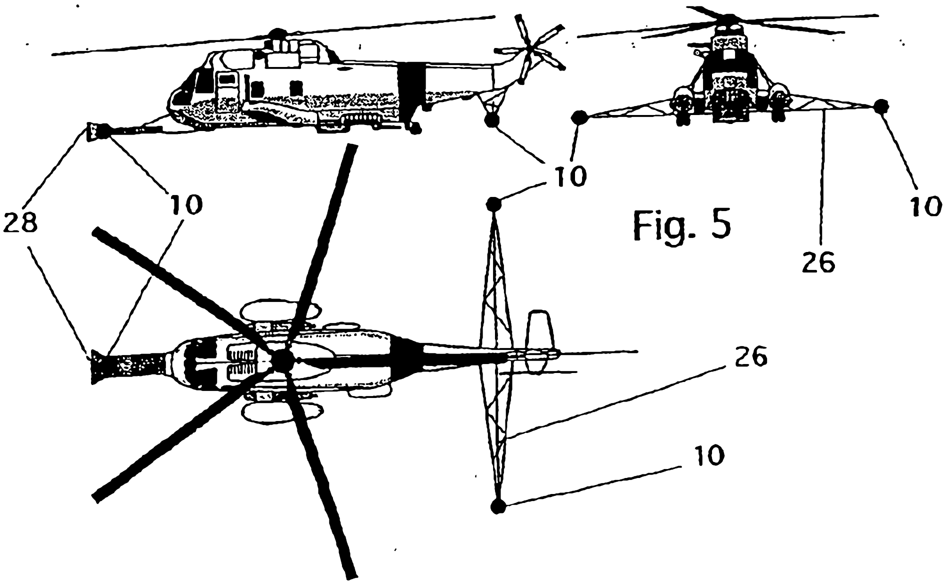


Fig. 5

Fig. 6

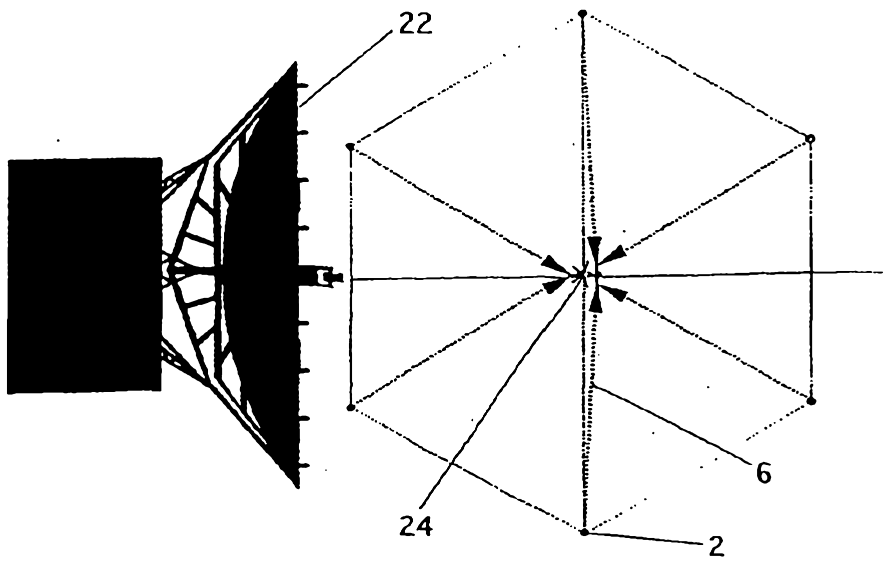


Fig. 7

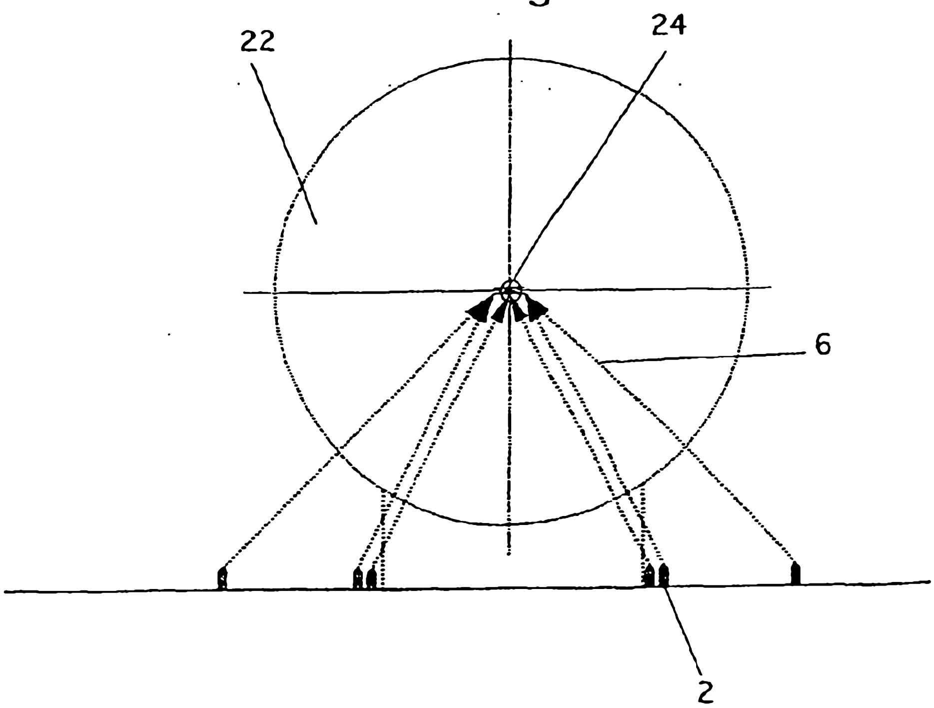


Fig. 8

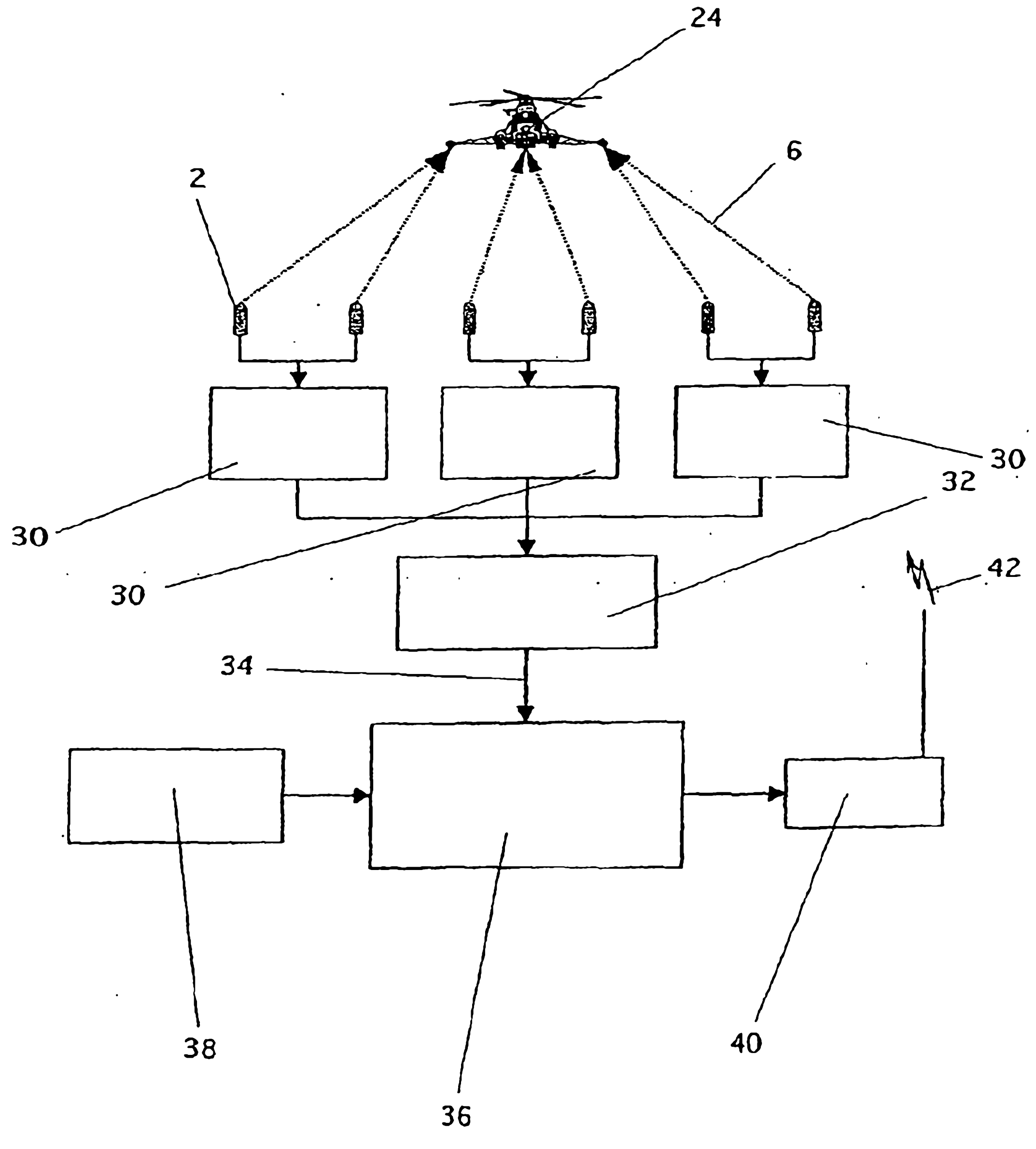


Fig. 9

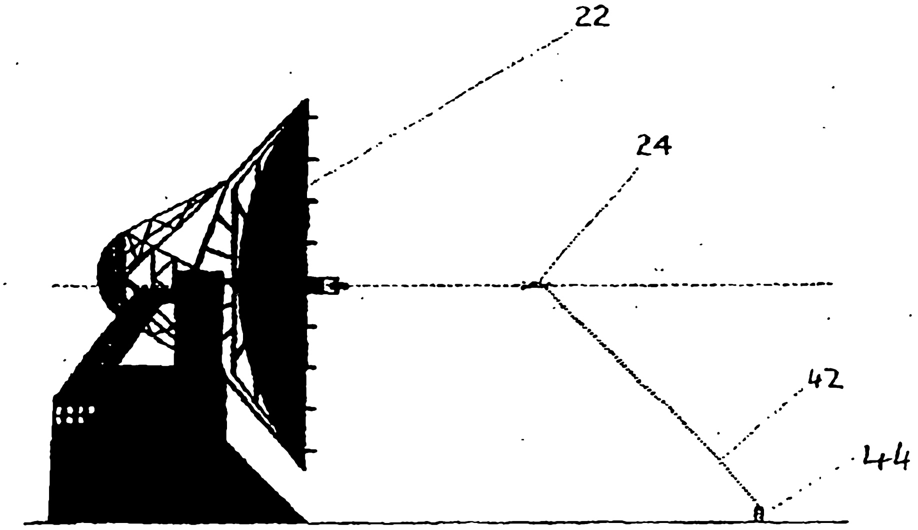


Fig. 10

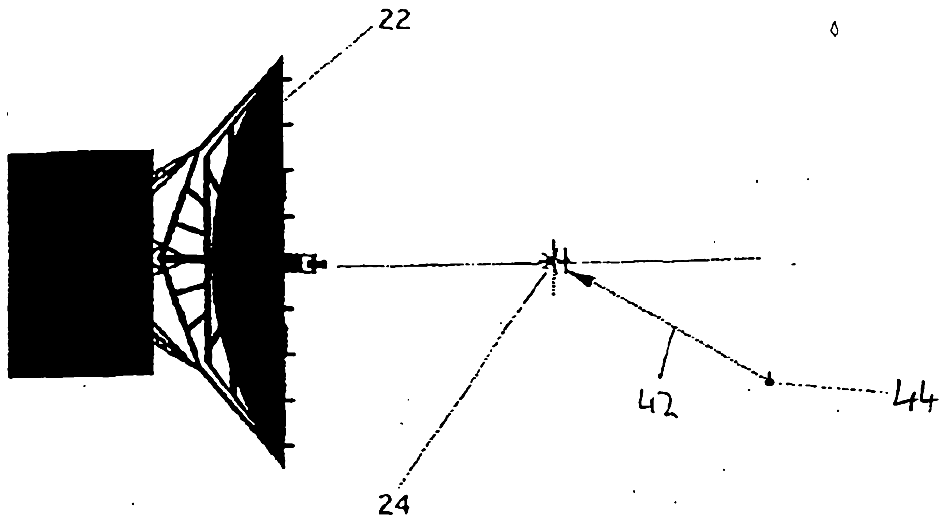


Fig. 11