(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 December 2024 (12.12.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/251371 A1

(51) International Patent Classification:
G01R 29/08 (2006.01)

(21) International Application Number:
PCT/EP2023/065496

(22) International Filing Date:
09 June 2023 (09.06.2023)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA,

(54) Title: CALIBRATION AND TESTING APPARATUS FOR RADIO-FREQUENCY DEVICES

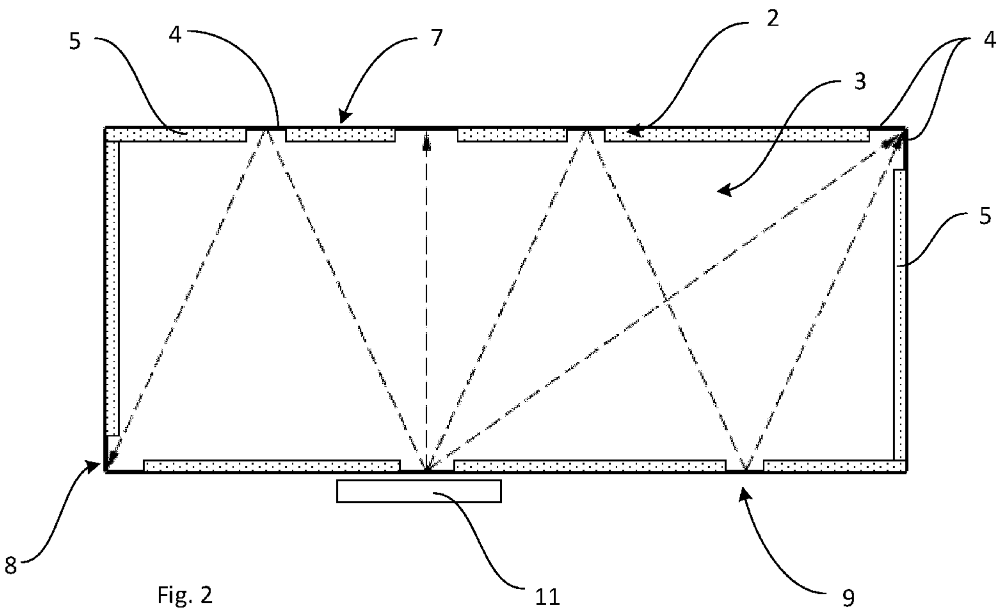

Fig. 2

(57) Abstract: A calibration and testing apparatus (1) for radio-frequency devices (11), said calibration and testing apparatus (1) comprising a closed housing (2) and a chamber (3) formed within said housing (2). The housing (2) comprises a first material (4) configured to substantially reflect radio-frequency signals emitted by said radio-frequency device, and a second material (5) configured to substantially absorb radio-frequency signals emitted by said radio-frequency device. Sections of first material (4) and sections of second material (5) are distributed throughout said housing (2) such that radio-frequency signals propagating at one or more predefined propagation angle(s) are reflected by said first material (4) and radio-frequency signals propagating at other angles are absorbed by said second material (5). The housing and chamber form a radio-frequency anechoic chamber comprising radio-frequency reflectors. The radio-frequency device (11) may for example be a radar, a mobile phone, a mobile terminal, or a standalone antenna.

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NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

CALIBRATION AND TESTING APPARATUS FOR RADIO-FREQUENCY DEVICES

TECHNICAL FIELD

The disclosure relates to a calibration and testing apparatus for radio-frequency devices, the calibration and testing apparatus comprising a housing.

BACKGROUND

Radio-frequency devices such as radars have to be calibrated and tested while in the production line.

A radio-frequency signal is emitted by the radar under test (RUT) and the signal travels to a corner reflector, representing a target, and back. Thereafter, the RUT resolves the distance to the reflector and its angular position. The obtained data can be compared with the real distance and angular position of the reflector, and calibration coefficients can be calculated.

Usually, radar calibration and testing is done in an anechoic chamber which is a large and expensive structure unsuitable for use in a production line. The RUT is placed on a turntable that is rotated, and the angular position relative the reflector as well the distance to the reflector, i.e. target, are measured. When hundreds of points are to be calibrated, the overall testing time becomes unacceptably high for production lines.

The anechoic chamber may be provided with several corner reflectors arranged at different angles, such that all directions can be tested and calibrated simultaneously. However, such a setup cannot be used for low range resolution radars since the targets cannot be separated in space. This requires the reflectors to be placed at different distances, the difference in distance being larger than the radar range resolution. This results in a very large anechoic chamber which is difficult to fit into a production line.

Furthermore, an anechoic chamber comprises a number of components that generate parasitic reflections indicating false targets, and that produce radio-frequency noise that can mask low power reflected signals.

Hence, there is a need to provide an improved calibration and testing apparatus for radio-frequency devices.

SUMMARY

It is an object to provide an improved calibration and testing apparatus for radio-frequency devices. The foregoing and other objects are achieved by the features of the independent claim. Further implementation forms are apparent from the dependent claims, the description, and the figures.

According to a first aspect, there is provided a calibration and testing apparatus for radio-frequency devices, the calibration and testing apparatus comprising a closed housing and a chamber formed within the housing. The housing comprises at least a first material configured to substantially reflect radio-frequency signals emitted by the radio-frequency device, and a second material configured to substantially absorb radio-frequency signals emitted by the radio-frequency device. Sections of first material and sections of second material are distributed throughout the housing such that radio-frequency signals propagating at one or more predefined propagation angle(s) are reflected by the first material and radio-frequency signals propagating at other angles are absorbed by the second material.

This solution allows a calibration and testing apparatus which is small in size, can be used for low range resolution radars, has a low overall testing time, and which does not indicate false targets.

In a possible implementation form of the first aspect, an interior surface of the housing comprises ≥90% of the second material, the interior surface delimiting the chamber. This reduces the amount of reflected signals, allowing only signals propagating at specific angles to be tested and calibrated.

In a further possible implementation form of the first aspect, the housing comprises one opening configured to accommodate a radio-frequency device to be calibrated and tested. By providing the housing with only one opening, an uninterrupted chamber suitable for testing and calibrating is formed.

In a further possible implementation form of the first aspect, the opening is configured to accommodate the radio-frequency device and allow the radio-frequency device to rotate at least an angle in a first plane, facilitating calibration and testing of several angles.

In a further possible implementation form of the first aspect, the calibration and testing apparatus further comprises a turntable configured to carry and rotate the radio-frequency device facilitating rotation of the radio-frequency device.

In a further possible implementation form of the first aspect, the walls of the housing are formed by the first material, sections of second material being interspersed within the walls or attached to the walls; or the walls of the housing are formed by the second material, sections of first material being interspersed within the walls or attached to the walls. This facilitates a structure where some signals are reflected and some signals are absorbed.

In a further possible implementation form of the first aspect, the sections of second material is arranged such that sections of first material are exposed to radio-frequency signals, allowing the radio-frequency signals to be reflected.

In a further possible implementation form of the first aspect, the housing comprises a third material, sections of first material being interspersed within the third material or attached to the third material. This allows using a material that has less internal reflection and/or is cheaper than the first material to be used for the main housing structure. It also allows the requirements on the second material to be lowered and the total cost of the apparatus to be decreased.

In a further possible implementation form of the first aspect, gaps between the sections of first material are covered by the second material, such that signals that are not to be tested are absorbed.

In a further possible implementation form of the first aspect, the second material covers the first material or the third material, and the second material comprises cut-outs forming openings exposing sections of first material. This facilitates a simple yet reliable structure for calibrating and testing radio-frequency signals.

In a further possible implementation form of the first aspect, several sections of first material are configured to form corner reflectors and/or individual sections of first material are configured to form flat reflectors, at least one of the corner reflectors and the flat reflectors being a target reflector. This allows the distance of travel of the signal, between radio-frequency device and target reflector, to be extended as the signal reflects from one reflector to another.

In a further possible implementation form of the first aspect, the flat reflectors are distributed throughout the housing such that radio-frequency signals can be reflected multiple times towards at least one target reflector. This allows the distance of travel of the signal, between radio-frequency device and target reflector, to be longer than the dimensions of the housing.

In a further possible implementation form of the first aspect, the apparatus is configured to fulfil far-field conditions between the radio-frequency device and the target reflector(s), facilitating calibration and testing at larger distances within a compact volume.

In a further possible implementation form of the first aspect, the sections of first material are embedded within the second material or the third material such that only one surface of each section of first material is exposed to radio-frequency signals. By preventing edges of the reflectors from being visible, radio-frequency scattering will be kept to a minimum.

In a further possible implementation form of the first aspect, the chamber is divided into sub-chambers by walls comprising the first material and/or the second material, increasing the flexibility of the apparatus.

In a further possible implementation form of the first aspect, the chamber and/or sub-chambers contain only air. Since there are no other electronics or mechanics inside the chamber except for the radio-frequency device, noise can be kept at a low level and the signal-to-noise ration can be improved. Furthermore, there are no sources of parasitic reflections preventing or at least reducing the occurrence of false targets

In a further possible implementation form of the first aspect, the housing and the chamber of the calibration and testing apparatus form a radio-frequency anechoic chamber comprising radio-frequency reflectors, facilitating calibration and testing of apparatuses such as radars, mobile phones, mobile terminals, and antennas.

These and other aspects will be apparent from the embodiments described below.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present disclosure, the aspects, embodiments and implementations will be explained in more detail with reference to the example embodiments shown in the drawings, in which:

Fig. 1 shows a schematic illustration of a calibration and testing apparatus in accordance with an example of the embodiments of the disclosure;

Fig. 2 shows a further schematic illustration of a calibration and testing apparatus in accordance with an example of the embodiments of the disclosure.

DETAILED DESCRIPTION

The present invention relates to a calibration and testing apparatus 1 for radio-frequency devices, the calibration and testing apparatus 1 comprising a closed housing 2, and a chamber 3 formed within the housing 2, the housing 2 comprising at least a first material 4 configured to substantially reflect radio-frequency signals emitted by the radio-frequency device, and a second material 5 configured to substantially absorb radio-frequency signals emitted by the radio-frequency device, sections of first material 4 and sections of second material 5 being distributed throughout the housing 2 such that radio-frequency signals propagating at one or more predefined propagation angles are reflected by the first material 4 and radio-frequency signals propagating at other angles are absorbed by the second material 5.

The calibration and testing apparatus 1 is suitable for calibrating and testing radio-frequency devices 11 such as radars, mobile terminals, and standalone antennas.

The calibration and testing apparatus 1 comprises, as shown in Figs. 1 and 2, a closed housing 2 and a chamber 3 formed within the housing 2. The chamber 3 may also be referred to as a multi-target wave channel. The figures show rectangular housings 2, however, the housing 2 may have any suitable shape.

The housing 2 comprises at least a first material 4 configured to substantially reflect radio-frequency signals emitted by the radio-frequency device, and a second material 5 configured to substantially absorb radio-frequency signals emitted by the radio-frequency device. In other words, the first material reflects radio-frequency signals emitted by the radio-frequency device and the second material absorbs radio-frequency signals emitted by the radio-frequency device. The first material 4 may be a metal and the second material 5 may be a radio-frequency absorber. The first material 4 may reflect more than 90 % of a signal and the second material 5 may reflect less than 10 %.

Sections of the first material 4 and sections of the second material 5 are distributed throughout the housing 2 such that radio-frequency signals propagating at one or more predefined propagation angles are reflected by the first material 4 and radio-frequency signals propagating at other angles are absorbed by the second material 5. Radio-frequency signals emitted by the radio-frequency device 11 propagate in accordance with the specific radio-frequency device 11 radiation pattern, and is absorbed throughout except at locations where the first material 4 is exposed, i.e., areas where the first material 4 forms reflectors. As an example, the propagation angles may be 0°, 20°, and 45°, the signals emitted at these angles being reflected while signals emitted at any other angles are substantially absorbed.

The interior surface 2a of the housing 2 may comprise ≥90% of the second material 5, the interior surface 2a delimiting the chamber 3. For example, the interior surface 2a of the housing 2 may comprise 98 % second material 5, the remaining 2 % being first material 4.

The housing 2 may comprise one opening configured to accommodate a radio-frequency device 11 to be calibrated and tested.

The opening may be configured to accommodate the radio-frequency device 11 and allow the radio-frequency device 11 to rotate at least an angle α in a first plane P, as suggested in Fig. 1. Preferably, the opening is just wide enough to accommodate the radio-frequency device 11 without unnecessary gaps.

The calibration and testing apparatus 1 may further comprise a turntable 6 configured to carry and rotate the radio-frequency device 11. The turntable 6 may be operated by a turntable control 12 and the turntable control 12 and radio-frequency device 11 may be interconnected via a computer 13. The radio-frequency device 11 is secured to the turntable 6 using a fixture, and the turntable control 12 allows the rotation of the radio-frequency device 11 in the first plane P, i.e. the xy-plane. At different angles α, the radio-frequency device 11 sends radio-frequency signals to, and receives signals from, the chamber 3 or multi-target wave channel. The transmitted and received signals are analyzed by the computer 13 such that calibration coefficients are obtained. The calibration coefficients are subsequently downloaded to the radio-frequency device 11. Thereafter, the radio-frequency device 11 is calibrated.

The walls of the housing 2 may be formed by the first material 4, sections of second material 5 being interspersed within the walls or attached to the walls. The housing 2 may, in other words, be made of metal. The walls, ceiling, and floor of the metal housing 2 are covered by radio-frequency absorber, the radio-frequency absorber comprising gaps, or being arranged such that there are gaps between sections of radio-frequency absorber, such that the metal is exposed in specific areas. These metal areas form reflective surfaces allowing the radio-frequency signals to be reflected. The walls, ceiling, and floor of the metal housing 2 may instead have the shape of a grid or skeleton, the housing 2 recesses in which the radio-frequency absorber is fitted.

Optionally, the walls of the housing 2 may be formed by the second material 5, sections of first material 4 being interspersed within the walls or attached to the walls. The housing 2 may, in other words, be made of a radio-frequency absorber. The walls, ceiling, and floor of the radio-frequency absorber housing 2 provided with metal sheets forming reflectors.

The sections of second material 5 may be arranged such that sections of first material 4 are exposed to radio-frequency signals, as illustrated in Fig. 2. In other words, the sections of second material 5 are organized to provide controllable multiple reflections.

The housing 2 may comprise a third material 7, sections of first material 4 being interspersed within the third material 7 or attached to the third material 7. The third material may be non-reflective and made of any suitable material such as wood, plywood, or plastic. This would be beneficial for cases where the radio-frequency path loss is high.

Any gaps between the sections of first material 4 may be covered by the second material 5.

The second material 5 may, in other words, cover the first material 4 or the third material 7, and the second material 5 may comprise cut-outs forming openings exposing sections of first material 4, i.e. windows being cut out from larger sections of second material 5.

Several sections of first material 4 may be configured to form corner reflectors 8 and/or individual sections of first material 4 may be configured to form flat reflectors 9, at least one of the corner reflectors 8 and the flat reflectors 9 being a target reflector. Corner reflectors 8 and flat reflectors 9 are illustrated in Fig. 2, which shows the corner reflectors as targets and the flat reflectors as means for signal propagation, i.e. the flat reflectors increase the distance from the radio-frequency device 11 to the targets without changing the size of the wave channel. The corner reflector may comprise two to four flat sections interconnected at one end to allow reflection within the corner reflector itself. The flat reflectors 9 may be a flat surface forming a mirror.

The flat reflectors 9 may be distributed throughout the housing 2 such that radio-frequency signals can be reflected multiple times towards at least one target reflector. This allows the distance of travel of the signal, between radio-frequency device 11 and target reflector, to be longer than the dimensions of the housing 2. The specific arrangement of the reflectors allows propagation of the signals only in specific directions, as shown by dashed lines in Fig. 2, as well as across large distances within a compact volume. This solution facilitates using several targets, e.g. for a radio-frequency device 11 in the form of a radar, as long as the radar range resolution of the radio-frequency device 11 is larger than the distance between targets. For example, a first target can be arranged at a first target distance from the radio-frequency device 11 and a second target can be arranged at a second target distance from the radio-frequency device 11. The distance between targets is calculated as the difference between the first target distance and the second target distance.

As an example, the radio-frequency device 11, or radar 11, can be configured to see two targets if the distance between the targets is greater than 0.6 m which is the radar's range resolution. Three targets are shown in Fig. 2, and they are placed in the chamber 3 at distances of 0.6 m, 1.2 m, and 1.8 m from the radio-frequency device 11 (RUT). The corner reflector indicated with reference numeral 8 is one target, and the diagonally opposite corner reflector, indicated by reference numeral 4, constitutes a target. Furthermore, the flat reflector directly opposite the frequency device 11 is one target. The remaining flat reflectors just reflect the signal.

The above-mentioned corner reflector, indicated by reference numeral 4, may constitute two targets. As shown in Fig. 2, two different paths, with different lengths, can lead to the same corner reflector, wherefore that one corner reflector is considered to be two targets.

The corner reflectors and flat reflectors can be arranged in any suitable way to allow any desirable paths and any number of targets, the target being formed by either corner reflectors or flat reflectors. This is applicable as long as the radar range resolution allows it, otherwise some of the paths should be blocked using the second material.

The apparatus 1 may be configured to fulfil far-field conditions between the radio-frequency device 11 and the target reflectors 8, 9.

The sections of first material 4 may be embedded within the second material 5 or the third material 7 such that only one surface of each section of first material 4 is exposed to radio-frequency signals. The surface of the section of first material 4 may be completely aligned with the corresponding surface of the second material 5. By preventing other reflector surfaces, such as the edges of the reflectors, from being visible, radio-frequency scattering, generated via that edge, will be kept to a minimum.

The chamber 3 may be divided into sub-chambers 3a by walls 10 comprising the first material 4 and/or the second material 5, as illustrated in Fig. 1.

The chamber 3 and/or sub-chambers 3a may contain only air. The chamber 3 and/or sub-chambers 3a do not comprise any electronics or mechanics that can affect the performance of the apparatus 1.

The housing 2 and the chamber 3 of the calibration and testing apparatus 1 may form a radio-frequency anechoic chamber comprising radio-frequency reflectors.

The various aspects and implementations have been described in conjunction with various embodiments herein. However, other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed subject-matter, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word “comprising” does not exclude other elements or steps, and the indefinite article “a” or “an” does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measured cannot be used to advantage.

The reference signs used in the claims shall not be construed as limiting the scope. Unless otherwise indicated, the drawings are intended to be read e.g., cross-hatching, arrangement of parts, proportion, degree, etc. together with the specification, and are to be considered a portion of the entire written description of this disclosure. As used in the description, the terms “horizontal”, “vertical”, “left”, “right”, “up” and “down”, as well as adjectival and adverbial derivatives thereof e.g., “horizontally”, “rightwardly”, “upwardly”, etc., simply refer to the orientation of the illustrated structure as the particular drawing figure faces the reader. Similarly, the terms “inwardly” and “outwardly” generally refer to the orientation of a surface relative to its axis of elongation, or axis of rotation, as appropriate.

CLAIMS

1. A calibration and testing apparatus (1) for radio-frequency devices (11), said calibration and testing apparatus (1) comprising

-a closed housing (2); and

-a chamber (3) formed within said housing (2);

said housing (2) comprising at least

--a first material (4) configured to substantially reflect radio-frequency signals emitted by said radio-frequency device, and

-a second material (5) configured to substantially absorb radio-frequency signals emitted by said radio-frequency device (11),

sections of first material (4) and sections of second material (5) being distributed throughout said housing (2) such that radio-frequency signals propagating at one or more predefined propagation angle(s) are reflected by said first material (4) and

radio-frequency signals propagating at other angles are absorbed by said second material (5).

2. The calibration and testing apparatus (1) according to claim 1, wherein an interior surface (2a) of said housing (2) comprises ≥90% of said second material (5), said interior surface (2a) delimiting said chamber (3).

3. The calibration and testing apparatus (1) according to claim 1 or 2, wherein said housing (2) comprises one opening configured to accommodate a radio-frequency device (11) to be calibrated and tested.

4. The calibration and testing apparatus (1) according to claim 3, wherein said opening is configured to accommodate said radio-frequency device (11) and allow said radio-frequency device (11) to rotate at least an angle (α) in a first plane (P).

5. The calibration and testing apparatus (1) according to any one of the previous claims, further comprising a turntable (6) configured to carry and rotate said radio-frequency device.

6. The calibration and testing apparatus (1) according to any one of the previous claims, wherein walls of said housing (2) are formed by said first material (4), sections of second material (5) being interspersed within said walls or attached to said walls; or

wherein said walls of said housing (2) are formed by said second material (5), sections of first material (4) being interspersed within said walls or attached to said walls.

7. The calibration and testing apparatus (1) according to claim 6, wherein said sections of second material (5) is arranged such that sections of first material (4) are exposed to radio-frequency signals.

8. The calibration and testing apparatus (1) according to any one of claims 1 to 5, wherein said housing (2) comprises a third material (7), sections of first material (4) being interspersed within said third material (7) or attached to said third material (7).

9. The calibration and testing apparatus (1) according to claim 8, wherein gaps between said sections of first material (4) are covered by said second material (5).

10. The calibration and testing apparatus (1) according to any one of the previous claims, wherein several sections of first material (4) are configured to form corner reflectors (8) and/or individual sections of first material (4) are configured to form flat reflectors (9), at least one of said corner reflectors (8) and said flat reflectors (9) being a target reflector.

11. The calibration and testing apparatus (1) according to claim 10, wherein said flat reflectors (9) are distributed throughout said housing (2) such that radio-frequency signals can be reflected multiple times towards at least one target reflector.

12. The calibration and testing apparatus (1) according to claim 11, wherein said apparatus (1) is configured to fulfil far-field conditions between said radio-frequency device (11) and said target reflector(s) (8, 9).

13. The calibration and testing apparatus (1) according to any one of the previous claims, wherein said sections of first material (4) are embedded within said second material (5) or said third material (7) such that only one surface of each section of first material (4) is exposed to radio-frequency signals.

14. The calibration and testing apparatus (1) according to any one of the previous claims, wherein said chamber (3) is divided into sub-chambers (3a) by walls (10) comprising said first material (4) and/or said second material (5).

15. The calibration and testing apparatus (1) according to any one of the previous claims, wherein said chamber (3) and/or sub-chambers (3a) contain only air.

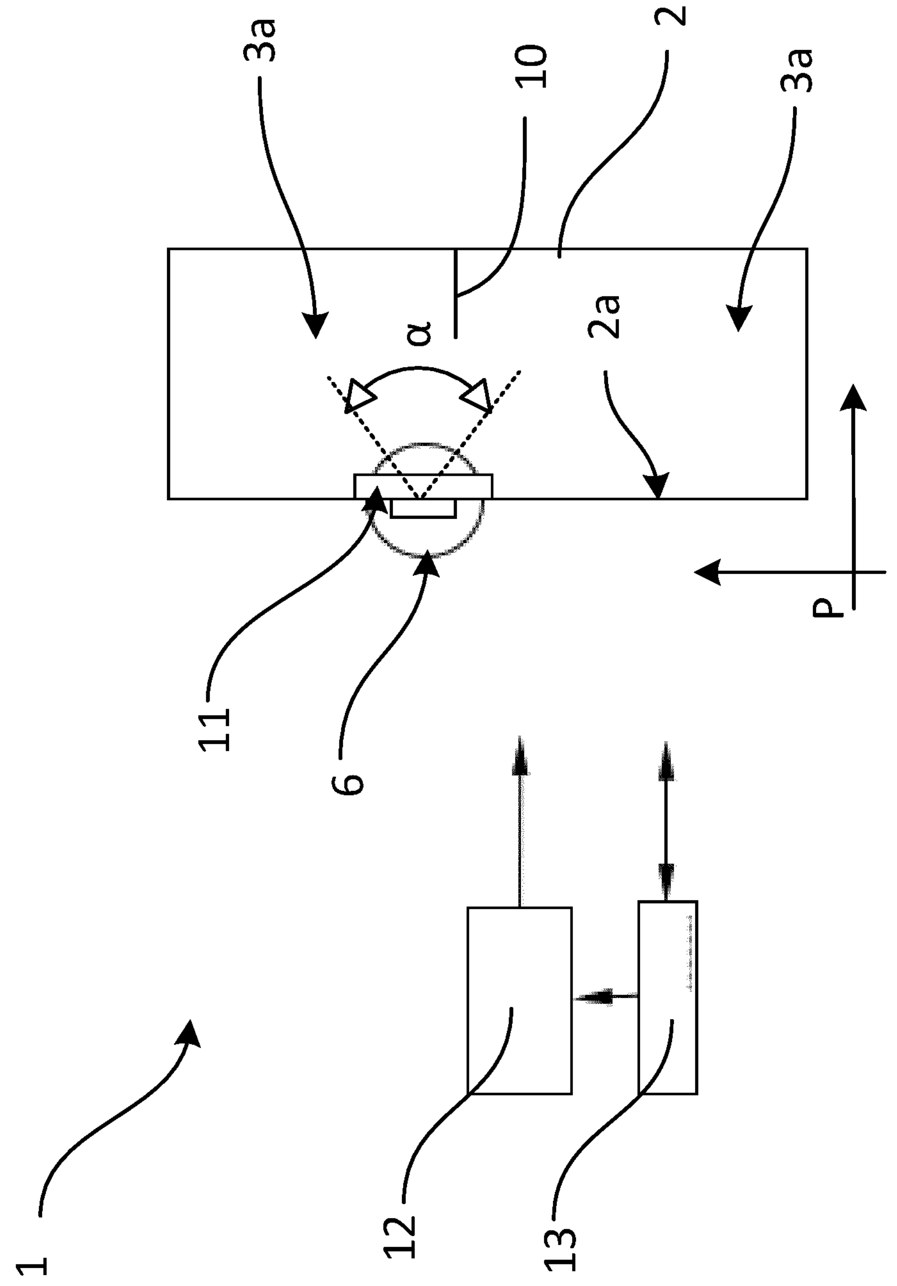

Fig. 1

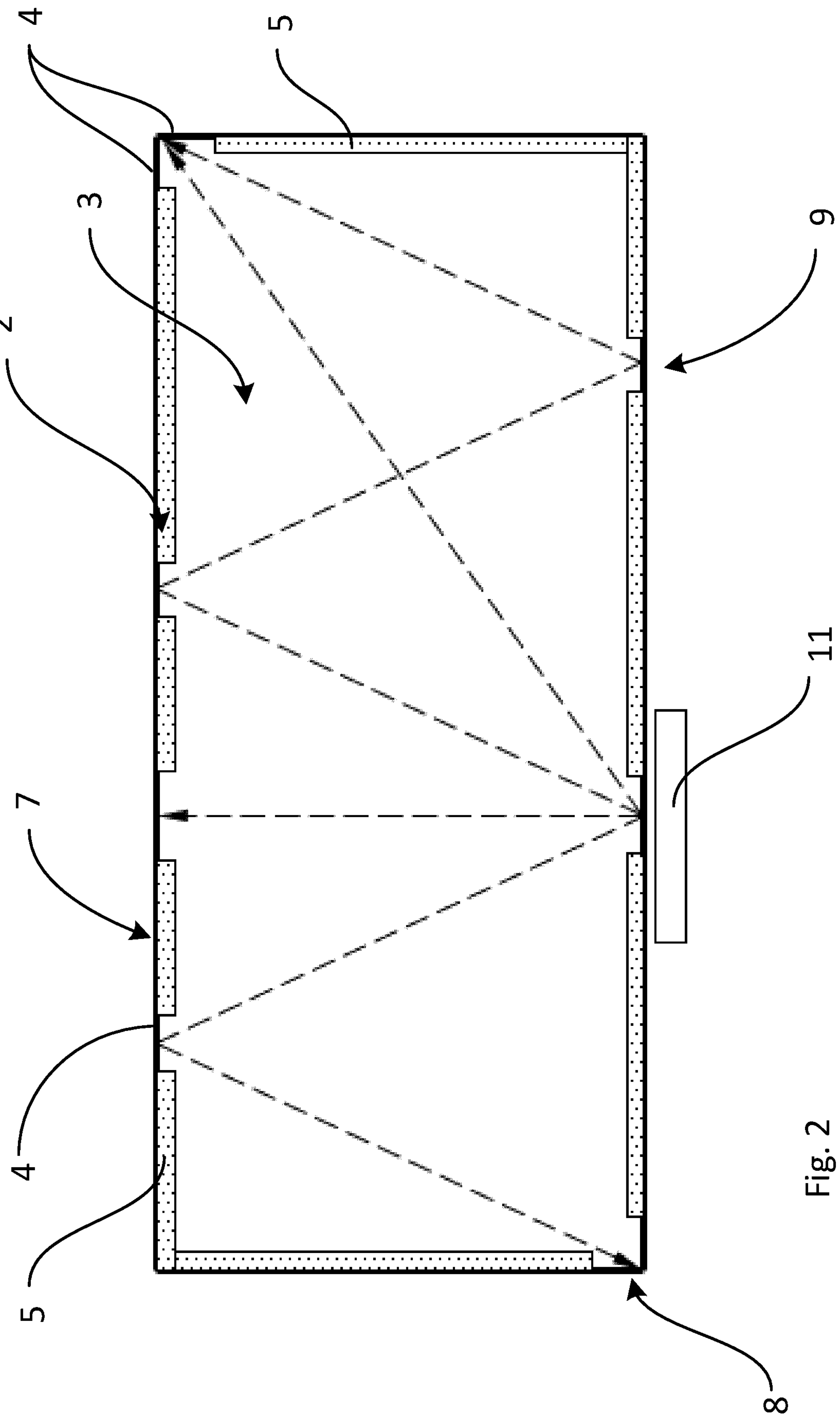

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/065496

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R29/08
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)
G01R G01S

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.
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A	CN 210 572 721 U (BEIJING DAORUIDA TECH CO LTD) 19 May 2020 (2020-05-19) claim 1; figures 1,2 -----	1-15
A	EP 3 971 605 A1 (ARGO AI LLC [US]) 23 March 2022 (2022-03-23) paragraph [0075] -----	1-15
A	CN 216 718 677 U (HANGZHOU SMART WAVE SCIENCE AND TECH LIMITED COMPANY) 10 June 2022 (2022-06-10) claim 1 ----- -/--	1-15

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2023	16/01/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Meliani, Chafik

1

International application No
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