

(19)



(11)

EP 2 887 455 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.06.2015 Bulletin 2015/26

(51) Int Cl.:
H01Q 3/08 ^(2006.01) **H01Q 1/28** ^(2006.01)
H01Q 21/06 ^(2006.01)

(21) Application number: **14198496.3**

(22) Date of filing: **17.12.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(30) Priority: **18.12.2013 IT RM20130695**

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(54) **Steerable antenna**

(57) A steerable antenna (1) is described, comprising:

- an orientable payload (4,5);
- an electromechanical movement and support system (6-10) operatively connected to the payload (4, 5) and adapted to orient the payload in a controlled manner, said electromechanical system comprising a base (6), a first motor (7) attached to the base (6), a driven pulley (8) operatively connected to the first motor (7) for being rotated around a first rotation axis, a second motor (9) operatively connected to the driven pulley (8) and oper-

atively connected to the payload (4, 5) for rotating the payload around a second rotation axis.

The steerable antenna (1) further comprises an electromechanical movement and support system (6-10) further comprises a support bracket (10) stably fixed to the base (6) to which the second motor (9) is pivotably hinged and wherein the driven pulley (8) is operatively connected to the second motor (9) for rotating the second motor (9) in relation to the base (6) and in relation to the support bracket (10).

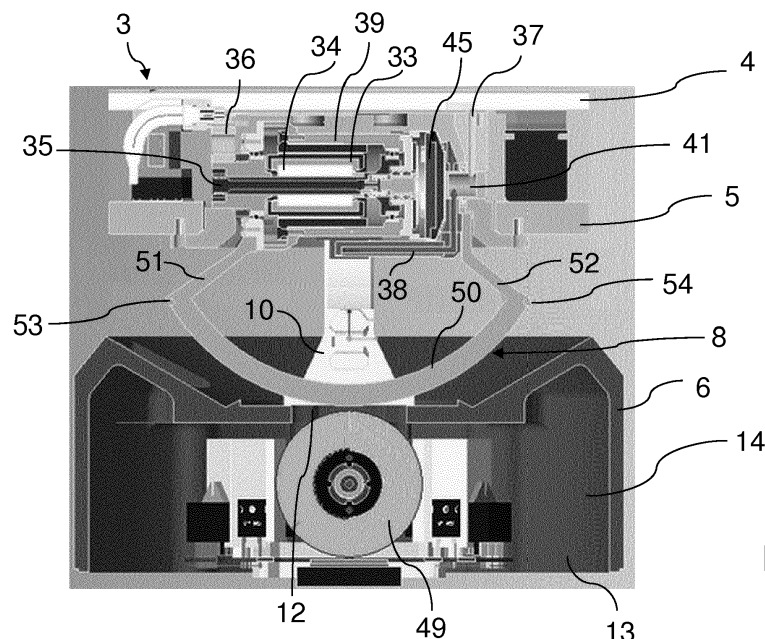


FIG. 5

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Description

[0001] The present description refers to the technical sector of steerable antennas.

[0002] Steerable antennas have been known of for a long time comprising an orientable receiver and/or transmitter device of electromagnetic radiation, the pointing direction of which can be controlled by means of an electromechanical movement and support system which makes it possible to orient the orientable reception and/or transmission device in space, for example to widen the scanning angle of the antenna. The orientable receiver and/or transmitter device of electromagnetic radiation is also referred to in general as payload.

[0003] In some cases, such as for example in the case of the steerable antennas of a missile seeker, the electromechanical movement and support system used is comparable to an altazimuth system and can be electronically controlled to enable the orientable reception and/or transmission device to rotate around two axes orthogonal to each other and to define a conical angle of aperture of the antenna beam.

[0004] Theoretically and in first approximation, the electromechanical movement and support system, or steering system, must guarantee highly accurate pointing, must be able to impart relatively high accelerations to the orientable receiver and/or transmitter device of electromagnetic radiation and must ensure a conical angle of aperture of the antenna beam that is as wide as possible.

[0005] The electronic control system of the electromechanical movement and support system is generally developed on the basis of a theoretical mechanical behaviour of the electromechanical movement and support system and various sensors on board the steerable antenna, for example position, and/or speed and/or gyroscopic sensors associated with the electromechanical movement and support system are used to create a closed-loop control. The result of the sensor reading is what is happening locally; it is therefore important that downstream of this reading there are no deformations or behaviours undetectable by the sensors which could lead to an incorrect command of the electromechanical movement and support system. These deviations from the standard are generally commonly referred to by the term aberrations. In theory the sensors should be placed as close as possible to the orientable receiver and/or transmitter device of electromagnetic radiation so that the control system always knows precisely its real location. A position distant therefrom, with a series of mechanical intermediate controls will introduce mechanical aberrations due to the imprecision of the pairings, elastic deformations of the system due to external stresses and imprecision in the machining of mechanical parts.

[0006] The ideal solution would be that of being able to couple the sensors directly under the orientable receiver and/or transmitter device of electromagnetic radiation coupled to the latter with rigid connections, without

intermediate mechanical controls. This solution however tends to limit the cone angle; and this all the more so the bigger the sensors (and motors) are. In this configuration, wishing to favour the performance in terms of angular acceleration (larger motors) will penalise the performance in terms of amplitude of the cone angle; vice versa wishing to favour the latter will penalise the performance in terms of angular accelerations inasmuch as making it more appropriate to use smaller motors.

[0007] A possible compromise between the performance in terms of angular acceleration and amplitude of the cone angle could be achieved by spacing the motors away from the payload, still rigidly connected to the orientable receiver and/or transmitter device of electromagnetic radiation; this would determine however an increase in the radius of the footprint sphere of the steerable antenna, which is problematic since the space available in the radome is limited. In addition the above solution, in the case of microwave antennas, requires a signal connection with shielded cable to the receiver and/or transmitter device of electromagnetic radiation, which affects the radio frequency performance and reduces the maximum power conveyable.

[0008] A different approach, relatively more widespread than that described above, is to position the motors and sensors away from the orientable receiver and/or transmitter device of electromagnetic radiation and to rely on intermediate mechanical controls, often rigid cardanic shafts and connecting rods, to move it. This makes it possible to use relatively bigger motors with a high torque and then rely on the quality of the mechanical construction and assembly to limit possible aberrations. In this configuration, there is a division between the rotation axes of the orientable receiver and/or transmitter device and the axes of the motors. This approach permits broader conical angles and high performance in terms of angular acceleration. However, the steerable antennas of the prior art made according to this approach have high costs, are structurally complex and require delicate adjustments during assembly.

[0009] The prior art also comprises steerable antennas in which the electromechanical system for moving and supporting the payload comprises a base, a first motor (or external motor) attached to the base, a driven pulley, a belt transmission connecting the first motor to the driven pulley so that it can be rotated around a first rotation axis (or external axis), a second motor (or internal motor) attached to the driven pulley and supported by it and adapted to rotate the payload around a second rotation axis (or internal axis). The two axes are uncoupled from each other: the movement of one does not affect the other; something hard to achieve with a system of connecting rods which are generally attached to the same drag element (antenna) despite being moved by two different actuators. This type of antennas of the prior art have various drawbacks, such as poor transversal rigidity, essentially but not exclusively due to the presence of the driven pulley which has a supporting function for the payload and

for the second motor.

[0010] A general purpose of the present description is to make available a steerable antenna which does not have the drawbacks mentioned above with reference to the prior art.

[0011] This and other purposes are achieved by means of a steerable antenna as defined in the first claim in its most general form, and in the dependent claims in some of its particular embodiments.

[0012] The invention will be clearer to understand from the following detailed description of its embodiments, made by way of a non-limiting example with reference to the appended drawings, wherein:

- Figure 1 shows a perspective and partial cross-section of a portion of a missile, comprising a radome and a steerable antenna;
- Figure 2 shows a perspective view of the steerable antenna in figure 2;
- Figure 3 shows a first view in lateral cross-section of the steerable antenna in figure 1;
- Figure 4 shows a perspective view of an embodiment of a support bracket of the steerable antenna in Figure 1;
- Figure 5 shows a second view in lateral cross-section of the steerable antenna in figure 1, in which the cross-section plane is perpendicular to the cross-section plane of the view in figure 3; and
- figure 6 shows a perspective view of an enlarged detail of the steerable antenna in figure 1.

[0013] In the appended drawings, elements which are the same or similar will be indicated using the same reference numerals.

[0014] Figure 1 shows a portion of an embodiment of a missile 1 comprising a radome 2 and a steerable antenna 3 mounted inside the radome 2. In the particular example shown and without thereby introducing any limitation, the steerable antenna 1 is the antenna of a radar and more in particular the antenna of a missile seeker. It should be noted, however, that the teachings of the present description are applicable without restriction to the particular type of steerable antenna in that the steerable antenna which the present description relates to could be any antenna utilisable for example in the telecommunications, terrestrial or satellite and scientific measurement instrument industries.

[0015] The steerable antenna 1 comprises an orientable payload 4, 5. For example, the orientable payload 4, 5 comprises at least one receiver and/or transmitter device of electromagnetic radiation 4. For example, the receiver and/or transmitter device of electromagnetic radiation 4 comprises a planar array antenna, for example a microwave and disc antenna comprising a plurality of antenna elements, such as patch antenna elements or slit antenna elements. Preferably, and without thereby introducing any limitation, the receiver and/or transmitter device of electromagnetic radiation 4 is both a receiver

and transmitter device.

[0016] According to one embodiment, the payload 4, 5 further comprises a processing circuit section 5 of the signals transmitted and/or received by the receiver and/or transmitter device of electromagnetic radiation 4.

[0017] The steerable antenna 1 further comprises an electromechanical movement and support system 6-10 operatively connected to the payload 4, 5 and adapted to orient the payload 4, 5 in a controlled manner.

[0018] The electromechanical movement and support system 6-10 comprises a base 6, a first motor 7 attached to the base 6 (or external motor 6), a driven pulley 8 operatively connected to the first motor 7 for being rotated around a first rotation axis (or external rotation axis), a second motor 9 (or internal motor) operatively connected to the driven pulley 8 and operatively connected to the payload 4, 5 for rotating the payload 4,5 around a second rotation axis (or internal rotation axis). The first and the second axes of rotation are perpendicular to each other.

[0019] The electromechanical movement and support system 6-10 further comprises a support bracket 10, for example as shown in figure 3, stably fixed to the base 6 to which the second motor 9 is pivotably hinged.

[0020] The driven pulley 8 is operatively connected to the second motor 9 for rotating the second motor 9 in relation to the base 6 and in relation to the support bracket 10.

[0021] According to an embodiment consistent with the example shown in the figures, the first motor 7 is positioned below the driven pulley 8 and the support bracket 10 on the opposite side to the payload 4, 5. Among other advantages this makes it possible, despite the presence of a powerful first motor and therefore significant dimensions, to avoid obstructing the movement of the payload 4, 5 and for example to make optimal use of the space in which the payload can be moved inside a radome.

[0022] Preferably, the first 7 and the second motor 9 are servomotors.

[0023] According to one embodiment, the base 6 is a cylindrical or substantially cylindrical container provided with an upper aperture 12 and a lower aperture 13. Preferably, the base 6 comprises a housing 14 inside which the first motor 7 is housed and attached. Preferably, the steerable antenna 1 comprises an electronic control circuit 15 of the first motor 7 also housed at least partially in the housing 14.

[0024] According to one embodiment, the base 6 comprises one or more attachment elements 16 adapted to permit the attachment of the base 6 inside the radome 2. For example, said attachment elements 16 comprise a plurality of recesses defined on the outer side walls of the base 6.

[0025] According to one embodiment, the upper aperture 12 of the base 6 allows the passage of at least one transmission element of the motion from the first motor 7 to the driven pulley 8.

[0026] With reference to figure 4, according to one embodiment, the support bracket 10 comprises a first end

portion 20, 21 firmly attached to the base 6 and a second opposite end portion 22, 23 to which the second motor 9 is pivotably hinged. For example, the first end portion 20, 21 is attached to the base by means of screws which cross through apertures provided in the first end portion 20, 21 to fit into corresponding apertures or internally threaded holes provided in the upper wall of the base 6.

[0027] Preferably, the support bracket 10 is fork-shaped, and the said second end portion 22, 23 comprises two end portions between which said second motor 9 is pivotably hinged.

[0028] More preferably, the aforesaid first end portion 20, 21 of the support bracket 10 comprises at least one attachment foot to the base 6 provided with a through aperture 26 crossed by the driven pulley 8 and non-interfering with the rotation of the driven pulley 8. In the example in figure 3, the aforesaid attachment foot 20, 21 comprises two attachment feet 20, 21 which are spaced apart and between which the aforesaid through aperture 26 crossed by the driven pulley 8 is defined.

[0029] According to a further embodiment, the support bracket 10 comprises two fork arms 24, 25 attached to the attachment foot 20, 21 of the support bracket 10 and the aforesaid second end portions 22, 23 are free end portions of said fork arms 24, 25. Preferably each of the aforesaid second end portions 22, 23 of the support bracket 10 comprises a respective through aperture 28, 29 having a circular, transversal cross-section. These through-apertures 28, 29 define a hinge axis and permit the pivotable hinging of the second motor 9 to the support bracket 10.

[0030] According to one embodiment 8, the support bracket 10 comprises a waveguide 30 integrated inside the bracket 10.

[0031] Preferably, the waveguide 30 is a channel defined in the thickness of the support bracket 10 and said bracket 10 is made of a metal material, for example steel.

[0032] With reference to figure 4, according to an advantageous embodiment, the support bracket 10 comprises two half-portions 26, 27 made in two separate pieces and juxtaposed and coupled to each other, for example by screws. This way, the realisation of the waveguide 30 integrated in the support bracket 10 is particularly easy since the waveguide 30 can be made by providing a first recess on a wall of one of the two half-portions 26, 27 intended to face an opposite wall of the other of the two half-portions. Clearly a second recess may also be provided on said opposite wall which is facing and aligned with the first recess when the two half-portions 26, 27 are coupled together.

[0033] In the case in which the support bracket 10 is fork-shaped with two fork arms 24, 25, the aforesaid channel preferably has a portion that extends inside one of said fork arms 24, 25. Preferably the aforesaid channel extends between two openings of the channel from the first end portion 20, 21 of the support bracket 10 to the second end portion 22, 23 of the support bracket 10 so as to define a waveguide 30 which extends from the base

6 of the steerable antenna 1 to the payload 4, 5. A waveguide connector may be provided on the base 6 arranged at the respective aperture of the channel.

[0034] With reference to figure 3, according to one embodiment, the steerable antenna 1 comprises a first rotary joint in the waveguide 31 having a portion of joint attached to the support bracket 10, at the second end portion 22, 23 which is operatively coupled to the integrated waveguide 30 and is in operational communication therewith and a second portion of joint operatively coupled to the payload 4, 5. Preferably, the second motor 9 is fixed to the second portion of the rotary joint in the waveguide, in the example shown, on the outside thereof. With joint reference to figures 3 and 5, in the particular example represented the first rotary joint in the waveguide 31 is attached to the arm 25 of the support bracket 10 and in particular engaged in the through aperture 29 and thus allows the second motor 9 to be pivotally hinged to the arm 25 of the support bracket 10. On the other side of the support bracket 10, a hinge pin 32 is preferably provided which includes a portion with a smooth surface engaged in the second motor 9 and a threaded portion screwed inside the through aperture 28 of the arm 24 of the support bracket 10.

[0035] According to one embodiment, the second motor 9 comprises a container body 39, a stator 33 housed inside the container body 39, a rotor 34 and a drive shaft 35 attached or coupled to the rotor 33. The container body 39 is fixed to the driven pulley 8 and is pivotably hinged to the support bracket 10 to rotate around the first rotation axis. The drive shaft 35 of the second motor 9 is directly or indirectly coupled to the payload 4, 5 by means of a first coupling flange 36. In the example shown in the figures a torque reducer is not provided, so that the coupling flange 36 is directly coupled to the drive shaft 35, for example keyed onto the drive shaft 35, and is directly coupled to the payload 4, 5. In an alternative embodiment the aforesaid coupling may be achieved by interposing a torque reducer.

[0036] According to one embodiment, a speed and/or position transducer 45 integral with the drive shaft 35 in its rotation around the second rotation axis is coupled to the drive shaft 35 of the second motor 9.

[0037] According to one embodiment, the payload 4, 5 is coupled to the external container 39 of the second motor 9 by means of a second coupling flange 37 and a second rotary joint 41, shown in figure 5. Preferably, the second rotary joint 41 and the coupling flange 37 are waveguide devices and make it possible to realise a waveguide connection by means of a link waveguide 38, operatively interconnected between the first waveguide joint 31 and the second waveguide joint 41 and integral in rotation with the second motor 9.

[0038] With reference to figure 5, according to one embodiment, the driven pulley 8 has an arch-shaped central portion 50 and two side arms 41, 42 attached to the container body 39 of the second motor 9. The rotation of the driven pulley 8 thus determines a rotation of the container

body 39 of the second motor 9 around the first rotation axis.

[0039] According to one embodiment, the first motor 7 comprises a container body 70, a stator 71 housed inside the container body 70, a rotor 72 and a drive shaft 73 attached or coupled to the rotor 72. The container body 70 is attached to the base 6. According to one embodiment, a speed and/or position transducer 74 is coupled to the drive shaft 73 of the first motor 7.

[0040] The drive shaft 73 of the first motor 7 is preferably coupled directly, i.e. without a torque reducer, to the driven pulley 8.

[0041] According to a preferred embodiment, the electromechanical support and movement system 6-10 comprises a belt transmission system, 18, 19, 48, 49 adapted to operatively couple the first motor 7 to the driven pulley 8 comprising two belts 18, 19 crossing each other having a first end portion attached to the driven pulley 8, wherein said transmission system 18, 19, 48, 49 comprises a drive pulley 48, 49 coupled to the first motor 7, and in particular to its drive shaft 73. The aforementioned belts 18, 19 each have a second end portion attached to the drive pulley 8. Preferably the second end portions of the belts 18, 19 are attached to opposite end portions 53, 54 of the rounded central portion 53, 58 of the driven pulley 8.

[0042] According to one embodiment, the aforementioned belts 18, 19 are made of a metal alloy, for example of an austenitic structure, nickel-chromium based, super alloy. Preferably, such belts have a reduced thickness, for example of the order of tenths of a millimetre, for example equal to a tenth of a millimetre.

[0043] According to one embodiment, the drive pulley 48, 49 comprises two parallel pulleys 48, 49, attached to each other by means of a coupling system which makes it possible to adjust the mutual orientation of said pulleys 48, 49 to ensure correct pre-tensioning of the belts 18, 19.

[0044] From the above description it is evident how a steerable antenna 1 of the type described above makes it possible to achieve the aforementioned purposes with reference to the state of the prior art.

[0045] The steerable antenna described above has in fact a very compact structure and a high transversal rigidity. The entire system, in fact, develops around a rigid central body consisting of the support bracket 10 and the base 6. The embodiment in which a waveguide integrated in the support bracket 10 is provided also appears to be particularly advantageous as it is possible to avoid providing a radio frequency cable which is moved during the manoeuvres of the steerable antenna.

[0046] Without prejudice to the principle of the invention, the embodiments and construction details may be varied widely with respect to what has been described and illustrated purely by way of a non-limiting example, without thereby departing from the scope of the invention as defined in the appended claims.

Claims

1. Steerable antenna (1) comprising:

- an orientable payload (4,5);
- an electromechanical movement and support system (6-10) operatively connected to the payload (4, 5) and adapted to orient the payload in a controlled manner, said electromechanical system comprising a base (6), a first motor (7) attached to the base (6), a driven pulley (8) operatively connected to the first motor (7) for being rotated around a first rotation axis, a second motor (9) operatively connected to the driven pulley (8) and operatively connected to the payload (4, 5) for rotating the payload around a second rotation axis;

characterised in that

the electromechanical movement and support system (6-10) further comprises a support bracket (10) integral with the base (6) to which the second motor (9) is pivotably hinged and the driven pulley (8) is operatively connected to the second motor (9) for rotating the second motor (9) in relation to the base (6) and in relation to the support bracket (10).

2. Steerable antenna (1) according to claim 1, wherein said support bracket (10) comprises a first end portion (20, 21) attached to the base (6) and a second end portion (22, 23) to which the second motor (9) is pivotably hinged.

3. Steerable antenna (1) according to claim 2, wherein said support bracket (10) is fork-shaped, and wherein said second end portion (22, 23) comprises two end portions between which said second motor (9) is pivotably hinged.

4. Steerable antenna (1) according to claim 3, wherein said first end portion (20, 21) of the support bracket (10) comprises an attachment foot to the base (6) provided with a through aperture (26) crossed by the driven pulley (8).

5. Steerable antenna (1) according to claim 4, wherein said attachment foot (20, 21) comprises two spaced-out attachment feet between which said through aperture (26) is defined.

6. Steerable antenna (1) according to claims 4 or 5, comprising two fork arms (24, 25) attached to the attachment foot (20, 21) and wherein said two end portions (22, 23) are free end portions of said fork arms (24, 25).

7. Steerable antenna (1) according to any of the previous claims, wherein the payload (4, 5) comprises a

transmission and/or reception device of electromagnetic radiation (4).

8. Steerable antenna according to claim 1, wherein the first motor (7) is positioned below the driven pulley (8) and the support bracket (10) on the opposite side to the payload (4, 5). 5
9. Steerable antenna (1) according to claim 1, wherein the support bracket (10) comprises an integrated waveguide (30). 10
10. Steerable antenna (1) according to claim 9, wherein said integrated waveguide (30) is a channel defined in the thickness of the support bracket (10) and wherein said channel has a portion which extends inside one of said fork arms (24, 25). 15
11. Steerable antenna (1) according to any of the previous claims, wherein the second motor (9) comprises a container body (39), a stator (33) housed inside said container body (39), a rotor (34) and a drive shaft (35) attached or coupled to the rotor (34), and wherein the container body (39) is attached to the driven pulley (8) and is pivotably hinged to the support bracket (10) to be able to rotate around said first rotation axis. 20 25
12. Steerable antenna (1) according to claim 11, wherein the driven pulley (8) has an arch-shaped central portion (50) and two lateral arms (51, 52) attached to the container body (39) of the second motor (9). 30
13. Steerable antenna (1) according to any of the previous claims, comprising a belt transmission system (18, 19, 48, 49) adapted to operatively couple the first motor (7) to the driven pulley (8) comprising two crossed belts (18, 9) having a first end portion attached to said driven pulley (8), wherein said transmission system comprises a drive pulley (48, 49) coupled to the first motor (7), wherein said belts (18, 19) each have a second end portion attached to said drive pulley (48, 49). 35 40
14. Steerable antenna (1) according to claim 13, wherein the drive pulley (48, 49) comprises two parallel pulleys (48, 49), attached to each other by means of a coupling system which permits adjustment of the reciprocal orientation of said parallel pulleys (48, 49). 45 50
15. Seeker comprising a steerable antenna (1) according to any of the previous claims. 55

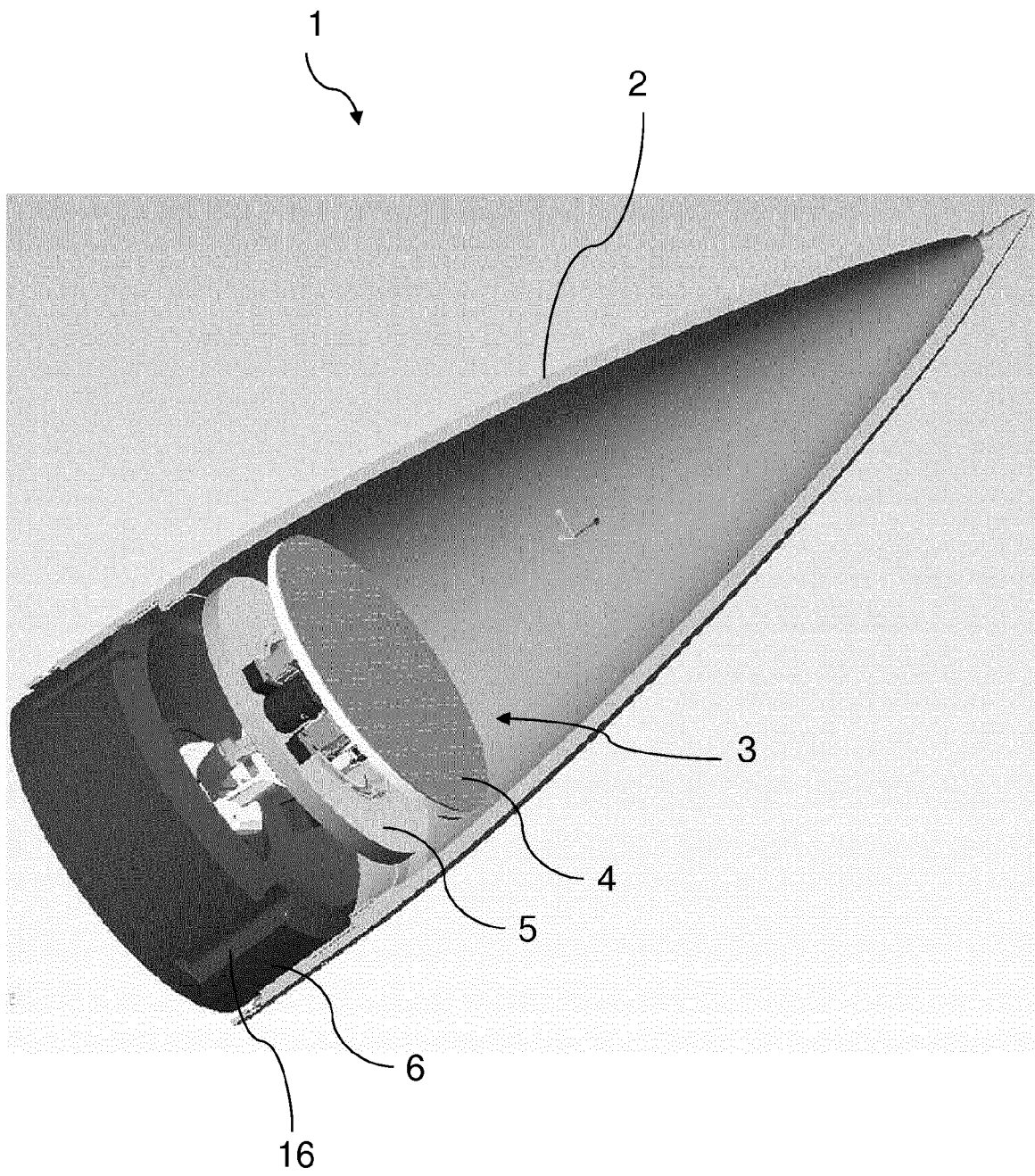
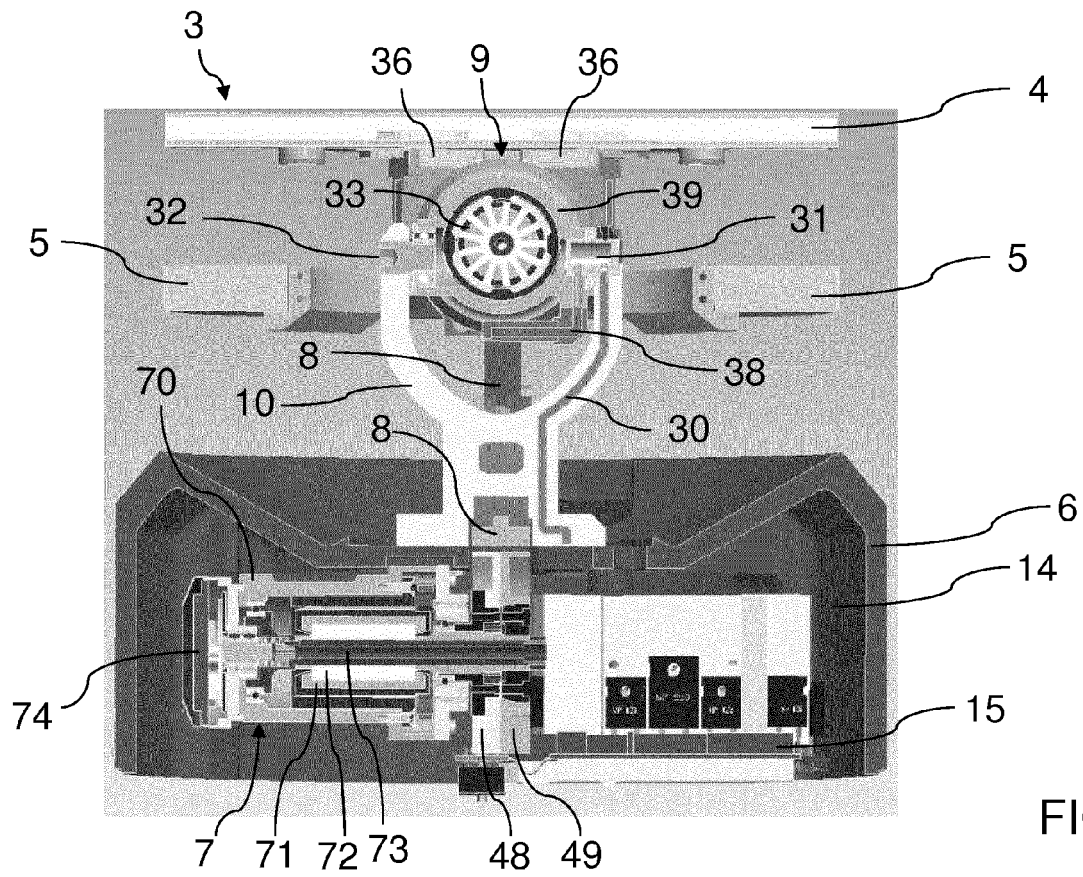
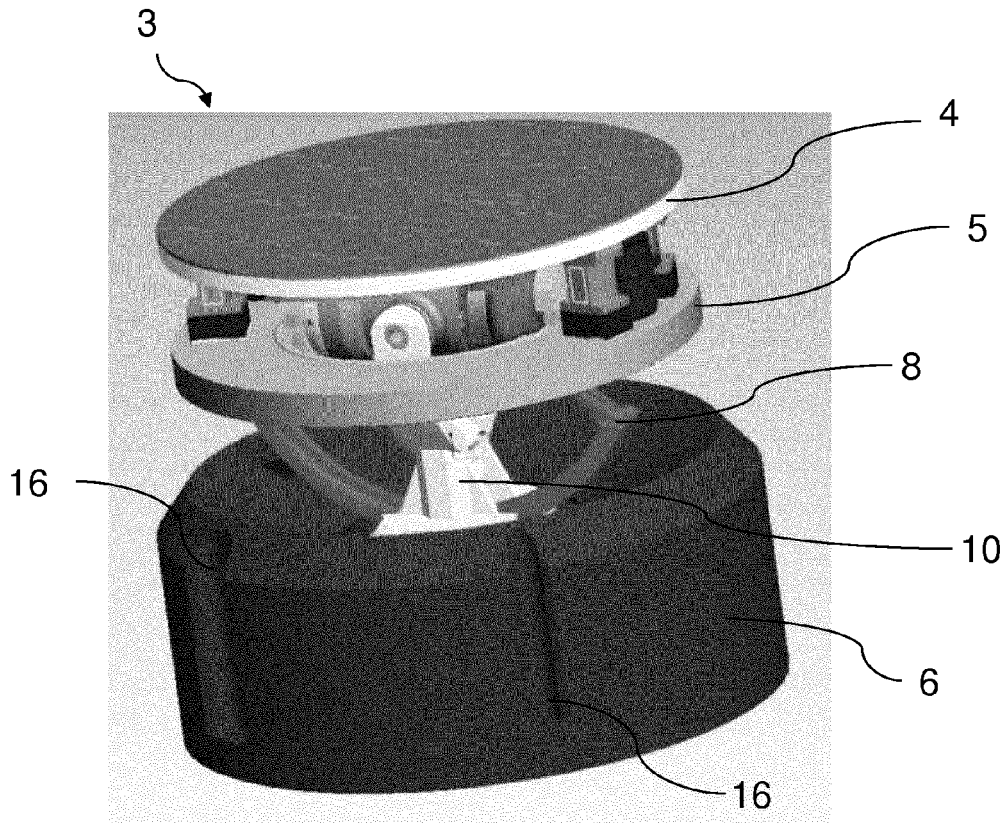


FIG. 1



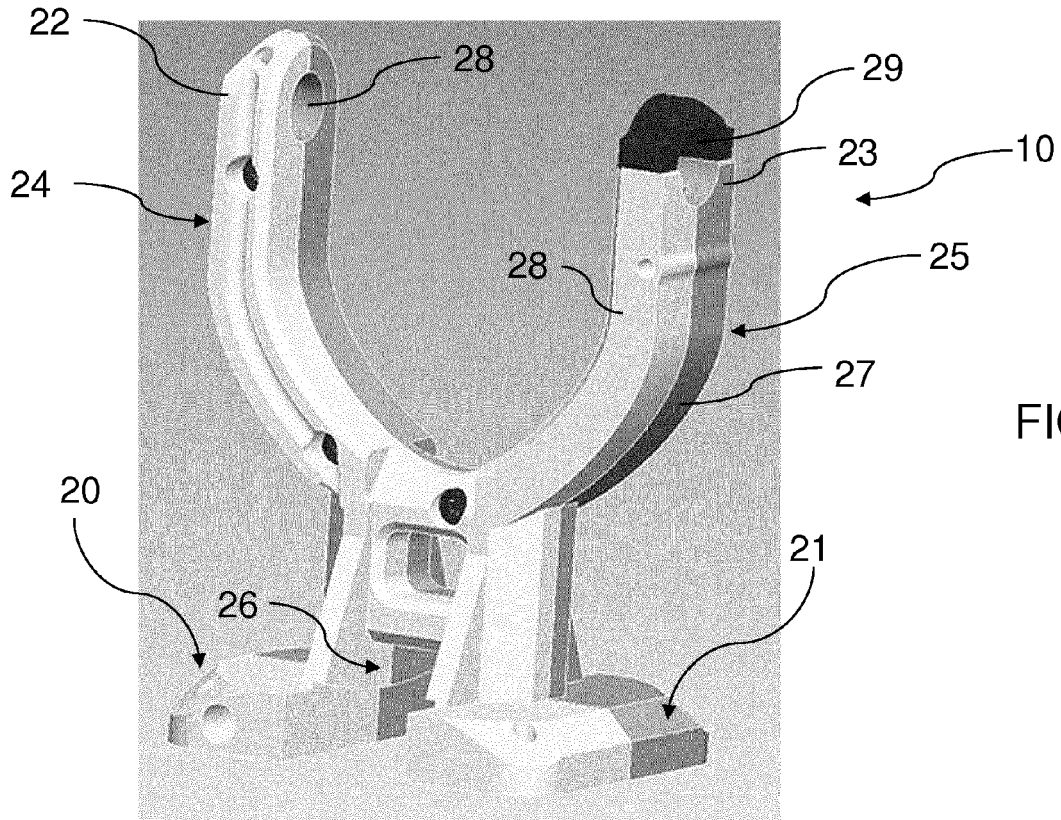


FIG. 4

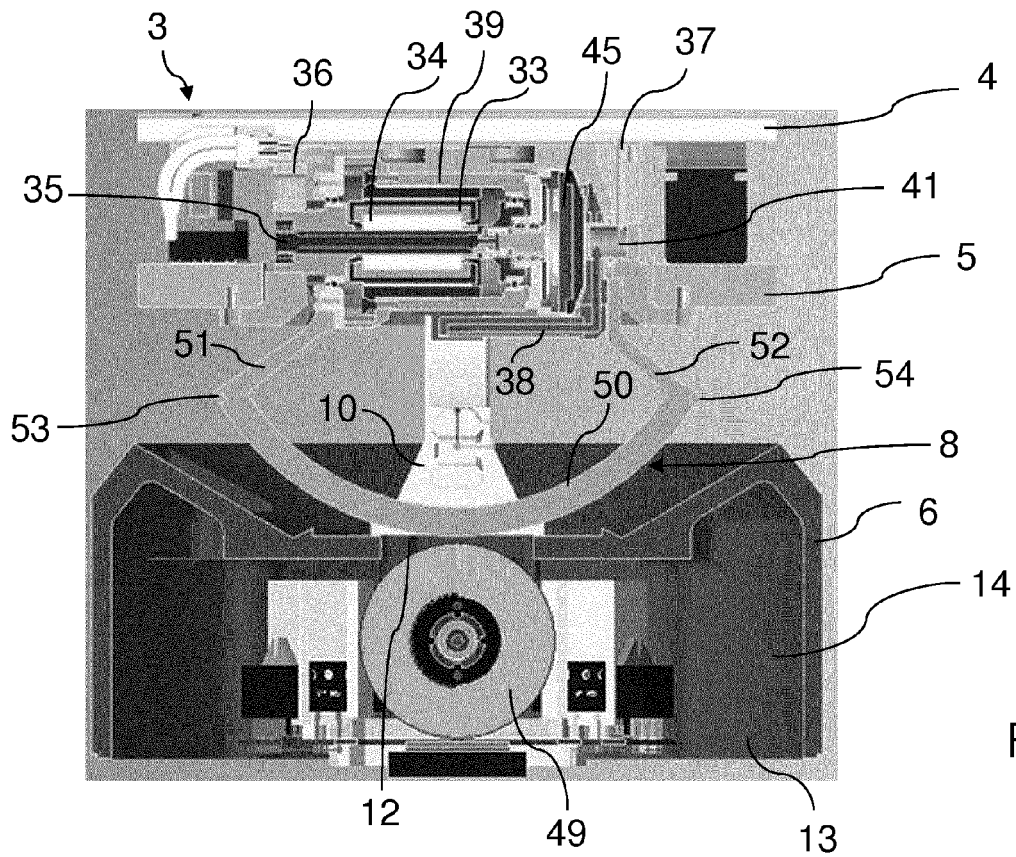


FIG. 5

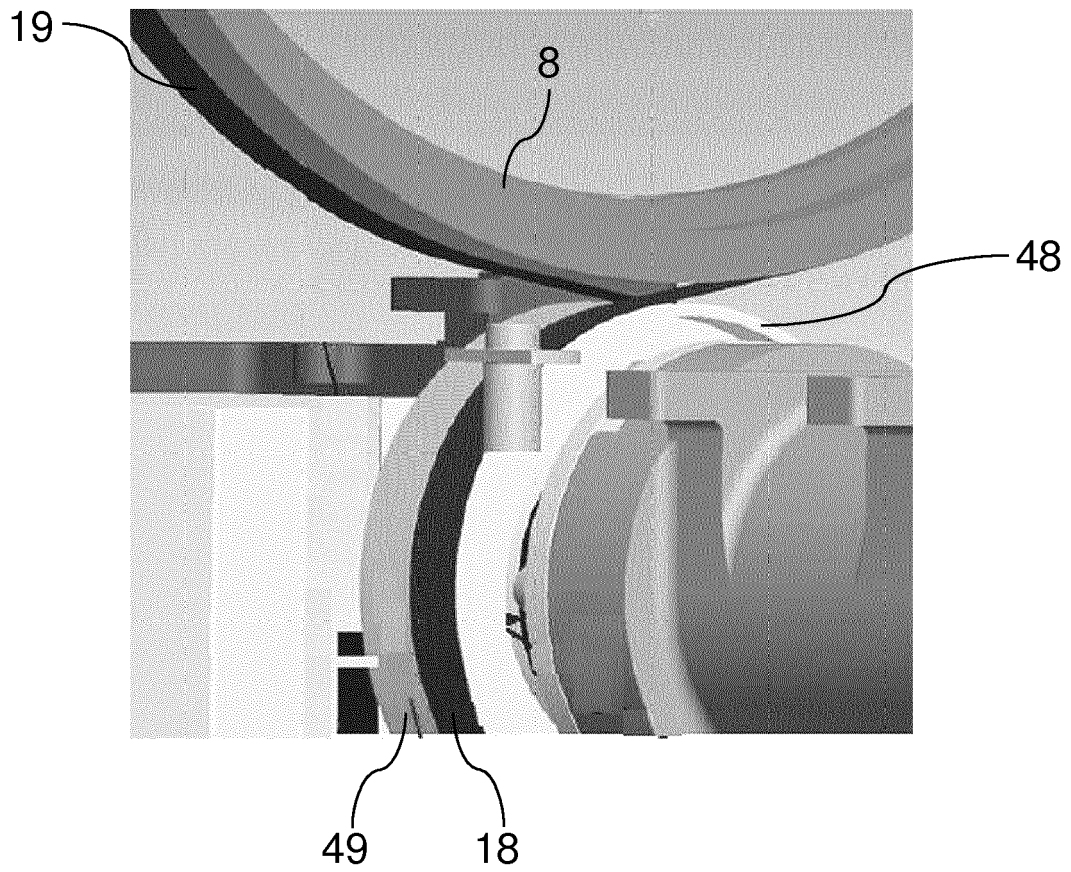


FIG. 6



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