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Antenna assembly including a micro-motor

Field of the invention

The present invention relates generally to an antenna assembly including an antenna rotated by a micro-motor.

5 Background of the invention

Many portable devices include an omni-directional antenna which is able to perform RF data transmission or reception. Such an antenna does not need to be scanned or steered in a correct direction before it is used, so an omni-directional antenna makes it possible for the portable device to respond to an
10 RF signal received from the surrounding space instantly, regardless of any shift in the user's position. However, the density of the electromagnetic field within such an antenna when an electromagnetic signal is received is lower than for a directional antenna, causing a reduction in the antenna gain. Conversely, since the antenna gain is linked to the radiation propagation
15 profile, the wide spread of radiation generated by the antenna lowers the RF beam power. In addition, it increases the risk of interfering with neighbouring wireless devices, as compared to an antenna with a focused radiation beam profile.

In the rather different field of antennas located on vehicles, it has been
20 proposed to rotate a focused radiating antenna to provide sufficiently high power transmission or reception over an increased range (i.e. an increased distance from the antenna). Such a device is illustrated in US 5,485,169, which shows an antenna rotated by a complex motor mechanism. The dimensions of the mechanism are not illustrated in this reference, but they are
25 clearly at least several centimetres. A relatively strong electromagnetic beam having the capacity to reach further than the field generated by an omni-

directional antenna is revolved in a complete circular path. In this way, the connectivity of the telecommunication signal can be improved.

Summary of the invention

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The present invention aims to provide a new and useful antenna assembly.

In general terms, the present invention proposes that an antenna assembly includes a micro-motor having a rotor, a stator and a drive mechanism for rotating the rotor relative to the stator. On the rotor are formed at least two
10 electrically conductive layers arranged to act as an antenna for generating a radio frequency (RF) electromagnetic beam. The two conductive layers are electrically coupled (either by electrical connection or by capacitance) to respective portions of the stator, so that the voltage between the conductive layers can be controlled (when an RF signal is to be transmitted) or measured
15 (when an RF signal is to be received).

By the term "micro-motor" is implied a device having dimensions on the order of millimetres. Such a device may be manufactured using a precision moulding process, such as injection moulding (e.g. using a polymer material), or using a semiconductor fabrication technique. In either case, the
20 manufacturing process is preferably as part of a batch process. Preferably, the maximum diameter of the rotor perpendicular to the axis is less than 10mm, such as about 7.5mm. Preferably the thickness of the rotor in the direction along the axis, and not including the shaft, is less than 5mm, and more preferably less than 2mm.

25 The resultant antenna assembly may be small enough to be incorporated into an item of consumer electronics, such as a portable telecommunication device, for example a wireless sensor system or mobile phone. Preferably the

item of consumer electronics is one having an electrically-insulating protective case. Unlike known antennas for mobile phones, certain embodiments of the present invention can generate an electromagnetic beam which is confined to a narrow angular width, so its RF strength is concentrated to reach further,
5 and without causing stray interference to any neighbouring devices.

Preferably, the present antenna assembly does not use surface reflection to steer the electromagnetic wave. Instead, the rotor preferably includes a wall extending parallel to the rotational axis of the rotor, and with at least part of the electrically conductive layers on its respective sides. The wall functions as
10 an antenna for reception and transmission of radio frequency energy. If the rotor is formed as a generally flat rotor disk, the wall may be upstanding from the plane of the rotor disk.

The stator may comprise a base and a shaft upstanding from the base. The base may, for example, be a circuit board such a printed circuit board (PCB).
15 The shaft on the stator may be threaded through a sleeve in the rotor disk. It may be formed of a metallic material.

The drive mechanism is preferably a brushless-motor. It comprises a permanent magnet attached to the rotor which interacts with drive circuitry formed on the stator to transmit electrical current through the magnetic field
20 generated by the permanent magnet, and thereby induce a torque to rotate the rotor disk. The drive circuitry may comprise multiple conductors located near to the surface of the permanent magnet to generate the required torque with minimum electrical input, and to maximize the induced energy for the rotation.

25 As in known micro-motors, the clearance between the rotating magnet and stationery coil winding is low, so their respective surfaces may come into physical contact should there be imbalance in the rotational motion, or if a shock is applied to the rotor. Similarly, there may be shocks when the rotor

disk collides with the shaft. Accordingly, damping is useful to stabilize the spinning motor whenever surface collisions occur. Some level of damping is provided if the rotor is formed including polymeric material which has natural elastic characteristics, since it provides direct cushioning to soften the collisions, and consequently reduce vibratory acoustic noise from the surface abrasions. Using material properties of the rotor to provide damping enables easier and cheaper production and assembly than using supplementary damping means, such as roller bearings.

A wear-resistant film such as diamond-like-carbon (DLC) may be formed on selected portions of the rotor and stator which may come into contact during rotation of the rotor, to reduce frictional resistance and increase the robustness of the antenna assembly.

The drive circuitry may be powered to rotate the rotor disk to direct the antenna to a required angular position, such as the one which is measured to have highest wave signal gain (and which is typically the direction towards a distant antenna with which the antenna assembly is communicating). The drive circuitry may for example be powered with electrical pulses, such that the rotor disk is rotated step-wise. Appropriate pulses may be generated by a processor.

The antenna assembly may include a system for tracking motion of the electronic device and accordingly compensating by rotating the rotor disk, to keep constant the direction in which the antenna is directed. Thus, the user can move about without the communication signal provided by the antenna assembly being lost.

Brief Description of The Figures

Preferred features of the invention will now be described, for the sake of illustration only, with reference to the following figures in which:

Fig. 1, which is composed of Figs. 1(a) and 1(b), shows an item of
5 consumer electronics including an antenna assembly which is a first
embodiment of the invention;

Fig. 2, which is composed of Figs. 2(a) and 2(b), shows the
construction of the antenna assembly of Fig. 1; and

Fig. 3 is another view of the antenna assembly of Fig. 1.

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Detailed Description of the embodiments

Referring firstly to Fig. 1(a) an application of an embodiment of the invention is shown as a component of an item 1 of portable consumer electronics, such
15 as a PDA, mobile phone, etc. The item 1 includes an embodiment of the
invention which is an antenna assembly 100 in a region indicated by the circle
10. The antenna assembly 100 includes a radiation wall 200, C-shaped in this
case, mounted at the radial edge of a rotor disk 101. As shown in Fig. 1(b),
the radiation wall 200 is capable of transmitting an electromagnetic beam 900
20 radially in a certain angular range, and of receiving electromagnetic radiation
which arrives from a direction within this range. The rotation of the rotor disk
101 carries the radiation wall 100 in a circular path so that the wall surface
moves through 360 degrees at a constant angular speed. Thus, the
electromagnetic beam 900 is rotated about the axis of the rotation, providing
25 telecommunication signal coverage in the user's surroundings.

The construction of the rotor assembly is shown in Fig. 2. The rotor disk 101
defines a sleeve extending along its axis of symmetry for receiving a shaft
106. The rotor disk also includes a ring-shaped step, creating a recess for

housing a magnet 102 and a yoke 103. The rotor disk 101 is mainly composed of a non-conductive dielectric material, but the rotor disk 101 has two electrically conductive surface layers (for example, of gold (Au) or titanium (Ti)) which function respectively as electrode layers. A first electrode layer 104
 5 having a thickness of about a tenth of a micrometer is formed by a conventional coating process on the inner concave surface of antenna wall 200, the sleeve wall of the rotor disk 101 and the upper planar surface (as viewed in Fig. 2(a)) of the rotor disk 101. As discussed below, this layer is grounded. The second electrode layer 105 is formed coating the outer radial
 10 surface of the antenna wall 200, the lower planar surface of the rotor disk 101 and the radially outer surface of the step. An appropriate thickness for each of the layers 104, 105 is several micrometers (for example, at least 2 micrometers, but less than 10micrometers). The layers 104, 105 together act as an antenna. Telecommunication is performed by controlling, or
 15 alternatively measuring, the voltages between the electrode layers 104, 105. The convex radially outer surface of the antenna wall 200 forms a radiating plane where an electromagnetic wave is generated due to charge carriers within the dielectric body of rotor disk 101.

The stator 120 for the antenna assembly includes a cylindrical pin shaft 106
 20 upstanding from a generally flat stationary stator body 120. Such a cylindrical profile can be fabricated from a steel rod by precision machining. The shaft 106 is formed with sufficiently high precision in relation to the size of the sleeve in order for the rotor body 101 to rotate around the shaft 106 with low eccentricity.

25 Friction between the sleeve and shaft 106 can be reduced by depositing a film of a material such as Diamond-Like-Carbon (DLC), of few micrometers in thickness, on the curved wall of the sleeve of the rotor disk 101. Deposition of such a layer provides a lubricating effect with good adhesion and chemically inertness. The film also has an extremely high mechanical hardness which

reduces wear and surface resistance at the contact. This makes the film desirable for a high-speed mechanism. The film may be deposited by sputtering or chemical vaporization, or by a Filtered-Cathodic-Vacuum-Arc (FCVA) process which can achieve a low-temperature conformal film at low
 5 temperature using a simple process to control the film thickness.

The mechanical force to drive the rotor assembly in a circular path, is induced by interaction between the permanent magnet 102 and thin electrical circuitry 110 located on the stator 120. The drive circuitry 110 has a thickness slightly more than the stator, and contains plated copper coil windings for generating
 10 electrical field to induce the required torque for the rotation.. Magnetic flux generated by the permanent magnet 102 is confined and concentrated to one side of the surface of the rotor disk 101 by covering the reverse (i.e. upper in Fig. 2(a)) surface of the permanent magnet 102 with a thin high-permeability machined Iron yoke plate 103. Through optimizing the area and magnetic field
 15 strength, the rotation direction and speed of the rotor disk 101 can be correctly controlled to move as intended. Taking into consideration of the dimensions of the proposed structure, it is suggested that the permanent magnet 102 is formed as a ring-shaped bond magnet 102 of uniform thickness composed of a material such as Samarium-Cobalt (Sm-Co)
 20 composite magnetic alloy. The permanent magnet 102, the yoke plate 103 and the rotor disk 101 can be fixed to each other using instant adhesive.

As shown in FIG. 2(b), the lower segment of cylindrical shaft 106 is integral with a shaft base 107 which projects radially outwardly from the shaft 106. The shaft base 107 may be 25% higher in diameter than the cylindrical shaft
 25 106. The shaft base 107 functions as a stationary platform for supporting part of the rotor assembly during the rotation. Another metallic ring 109, preferably made of steel, is provided encircling the base of the shaft 106 at the base section. The upper surface of the ring 109 is preferably at the same height as the upper surface of the shaft base 107, so the ring 109 forms a second

stationary platform. The shaft base 107 and the ring 109 are separated and mutually electrically isolated by a polymer adhesive layer 108 which is sandwiched between the radial wall surfaces of conductive bases 107, 109 in the production process and which holds the metallic components 107, 109 in place in the antenna assembly,

As the rotor disk 101 rotates at a fixed speed its lowest portion rests against the two support platforms 107, 109. The electrode layer 104 is in electrical contact with the shaft base 107, in the region marked 301 in Fig. 3. The shaft base 107 grounds the layer 104 electrically. Concurrently, the electrode layer 105 is in electrical contact with the ring 109, in the region marked 302 in Fig. 3. Electrical RF circuitry is provided which is in electrical contact with the ring 109, and this circuitry can establish a data signal link out of the antenna assembly using the rotor disk 101 as an antenna.

The electrical connection 121 between the shaft base 107 and the earth, and the electrical connection 122 between the ring 109 and the RF circuitry, are provided by two respective conductor leads which are fixed to the stator 120.

The stator 120 may actually be a circuit board, such as a common printed circuit board (PCB), and in this case any of the electrical connections 121, 122 and the drive circuitry 110 may be thin electrical conductor patterns manufactured by precision wiring technology on the surface of the board. The geometry of each of the conductor leads is carefully selected so that a robust communications route can be established between the stationary and moving bodies, without stray electromagnetic interference.

At the end of the process of assembling the antenna assembly, a small conductive metal ring 111 is attached at the upper end of the steel shaft 106, just above the top surface of the rotor disk 101. This ring 111 restricts the axial displacement of the rotor disk 101 to assure undisturbed and consistent electrical connection between the rotor disk 101 and the PCB 120.

Preferably, the maximum diameter of the rotor perpendicular to the axis is less than 10mm, such as about 7.5mm. The thickness of the rotor in the direction along the axis, e.g. measured from where the lowest part of rotor meets the shaft (i.e. the lowermost part of the layer 104), to the location
 5 furthermost from the stator (i.e. the uppermost part of the layer 104) is less than 5mm, and more preferably less than 2mm.

Although the layers 104, 105 are shown in Fig. 2 collectively covering almost all the surface of the rotor disk 101, this is not a necessary feature of the embodiment. For example most of the layer 104 on the upwardly facing
 10 surface of the rotor disk 101 can be omitted, provided that a conduction path exists from the shaft base 107 to the concave surface of the wall 200. Similarly, most of the layer 105 on the downwardly facing surface of the rotor disk 101 can be omitted, provided that a conduction path exists from the ring 109 to the convex surface of the wall 200.

15 The drive circuitry 110 is powered to rotate the rotor disk 101 to direct the antenna to a required angular position, such as the one having highest wave signal gain. The circuitry 110 may for example be powered with electrical pulses, such that the rotor disk 101 is rotated step-wise. Appropriate pulses may be generated by a processor located on the PCB 120. The system may
 20 include a system for tracking motion of the electronic device 1 (i.e. motion of the user) and accordingly compensating by rotating the rotor disk 101, thereby by keeping constant the direction in which the beam 900 is directed. Thus, the user can move about without the communication signal provided by the antenna assembly being lost. Alternatively, or additionally, the processor may
 25 use a feedback mechanism in which it constantly measures the quality of communication and varies the angle of the rotor to maximise this quality.

The rotor disk 101 functions both as a revolving platform and as a micro-antenna. In order to play these two roles, it is preferably constructed by

moulding a material having two key material characteristics: a high dielectric constant, and a high structural rigidity to produce damping naturally. The former characteristic enhances the efficiency of electromagnetic coupling in the antenna, while the latter characteristic gives the advantage of shock resistance to the mechanical bearing. Other desired properties in selecting the material of the rotor disk 101 include robust molecular bonding and durability against thermal deficiency. Most engineering plastics are applicable for the intended mechanical purpose, among them, polymers with a high dielectric constant (κ) such as Poly-Vinylidene-Di-Fluoride (PVDF).

In the fabrication of the proposed thin rotary device 100 requires a high precision approach to carefully reduce the thickness of each component to the desired dimensions without overly sacrificing structural rigidity. The micro-fabrication of the rotor disk 101, which cannot be attained from conventional machining technology, is preferably achieved using a precision injection moulding method. In the process, multiple identical components may be made in batches with accurate control of surface smoothness as well as the tolerances for the bearing clearances.

Like the inner surface of the sleeve of the rotor disk 101, the radial surface of the shaft 106 is also coated with DLC to reduce probable radial contact resistance during the spinning. However, the upper (in Fig. 2(a)) planar surfaces of the shaft base 107 and outer contact ring 109 are not coated with DLC to enable them to make good electrical contact with the electrode layers 104, 105 of the rotor disk 101.

In other embodiments, the antenna assembly may be varied such that electrical signals can be communicated to one or both of the conductive layers 104, 105 without them physical contacting the stator. This can be achieved by arranging for each conductive layer 104, 105 to be electrically in contact with a respective first electrically conductive surface positioned very

close to a respective second electrically conductive surface on the stator. Capacitance between the respective first and second conductive surfaces can then be used to transmit signals to the layers 104, 105 when there is sufficient electrical potential across them.

- 5 Although only a single embodiment of the invention has been described, many variations are possible within the scope of the invention, as will be clear to a skilled reader. For example, the geometry of the wall 200 may be modified to fit the RF propagation requirements of the application.

Claims

1. An antenna assembly including a micro-motor having a rotor, a stator and a drive mechanism for rotating the rotor relative to the stator,
 at least two electrically conductive layers being formed on the rotor, the
 5 conductive layers being electrically coupled to respective portions of the stator and being arranged to act as an antenna for generating a radio frequency (RF) electromagnetic beam.
2. An antenna assembly according to claim 1 in which the rotor comprises:
 10 a rotor disk defining a sleeve for receiving a shaft of the stator; and
 a wall upstanding from the disk, at least part of the electrically conductive layers being located on respective sides of the wall.
3. An antenna assembly according to claim 2 in which the wall is convex on its surface directed away from the axis of the rotor disk.
- 15 4. An antenna assembly according to claim 2 or claim 3 in which the rotor disk and wall include dielectric material having a dielectric constant of at least 3.
5. An antenna assembly according to claim 2, claim 3 or claim 4 in which the rotor disk and wall include polymer material.
- 20 6. An antenna assembly according to any of claims 2 to 5 in which a friction-reducing film is formed on at least part of the inner surface of the sleeve and/or the outer surface of the shaft.

7. An antenna assembly according to any preceding claim in which the stator is a printed circuit board (PCB).
8. An antenna assembly according to any preceding claim in which the rotor includes a permanent magnet and the stator includes drive circuitry for
5 generating an magnetic field to interact with the magnetic field of the permanent magnet.
9. An antenna assembly according to any preceding claim further including a processor arranged to power the drive mechanism to rotate the rotor relative to the stator to direct the antenna to a required angular position.
- 10 10. An antenna system according to claim 9 including a motion sensor for tracking motion of the stator, the processor being arranged to compensate for the motion by rotating the rotor disk to keep constant the direction in which the antenna is directed.
11. An antenna assembly according to any preceding claim in which the
15 conductive layers include respective first conductive surfaces which make sliding contact with respective second conductive surfaces on the stator.
12. An antenna assembly according to any preceding claim in which the conductive layers include respective first conductive surfaces capacitatively coupled to respective second conductive surfaces on the stator.
- 20 13. A portable consumer electronics item including an antenna assembly according to any preceding claim.