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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 November 2001 (15.11.2001)

PCT

(10) International Publication Number
WO 01/86749 A2

(51) International Patent Classification[7]: H01P 1/00

(21) International Application Number: PCT/GB01/02073

(22) International Filing Date: 10 May 2001 (10.05.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0011301.9 10 May 2000 (10.05.2000) GB

(71) Applicant *(for all designated States except US)*: **TRANSENSE TECHNOLOGIES PLC** [GB/GB]; 77 Cherwell Innovation Centre, Heyford Park, Upper Heyford, Bicester, Oxfordshire OX6 3HD (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **LONSDALE, Anthony** [GB/GB]; Balscote Mill, Balscote, Banbury, Oxfordshire OX15 6EY (GB). **LONSDALE, Bryan** [GB/GB]; Balscott Mill, Balscote, Banbury, Oxfordshire OX15 6EY (GB).

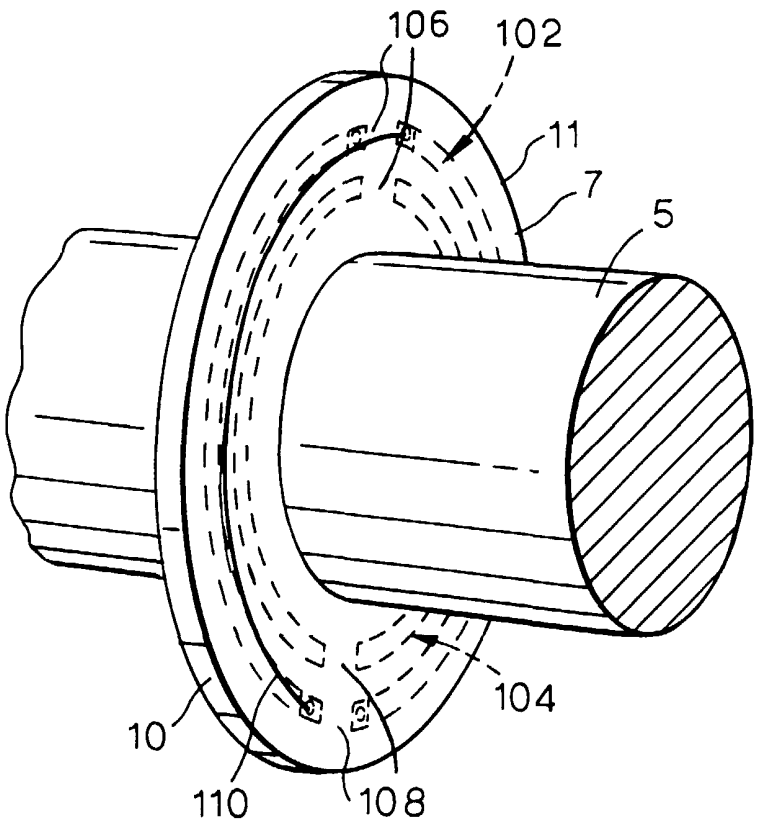
(74) Agents: **GOODENOUGH, Nigel** et al.; A.A. Thornton & Co., 235 High Holborn, London WC1V 7LE (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, 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) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European 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).

[Continued on next page]

(54) Title: AN IMPROVED ROTARY SIGNAL COUPLER



(57) Abstract: The present invention relates to a rotary signal coupler, that is to say a device for providing signal coupling between two components which are rotatable relative to each other. A coupler is provided comprising a first substantially circular track secured to a first support (not shown) and a second substantially circular track (102) secured to a second support (10) which is rotatable relative to the first support. The first and second tracks are coaxial with the axis of rotation of the rotatable second support (10) and are adjacent each other so as to provide signal coupling therebetween. The second track (102) has at least two gaps (106, 108) therein which form electrical discontinuities between separated track portions. The separated track portions are electrically connected (110) to one another. Signal coupling with a rotatable support having a relatively large diameter may be thereby improved.

WO 01/86749 A2

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

AN IMPROVED ROTARY SIGNAL COUPLER

This invention relates to a rotary signal coupler, that is to say a device for providing signal coupling between two components which are rotatable relative to each other.

Published International patent application WO 91/13832 describes a strain measuring method and apparatus particularly suitable for measuring the torque applied to a shaft. The described method and apparatus make use of a surface acoustic wave (SAW) device mounted on the shaft. Such devices require the passage of high frequency, typically radio frequency (RF), signals between the SAW device and its associated drive/measuring circuitry. If the shaft to which the SAW device is attached rotates only through a small angular range, the SAW device may be hard wired to its associated drive/measuring circuitry. There are, however, many applications of the torque measuring technique described in WO 91/13832 which are not susceptible to hard wiring between the SAW device and its associated drive/measuring circuitry, and such applications require the use of a rotary signal coupling device in order to effect the required connection.

Published International patent application WO 96/37921 discloses a rotary signal coupling device which may be used to provide the required coupling to a SAW device at RF frequencies. The described device includes a pair of transmission lines, each comprising an electrically conductive track and an associated ground plane. The tracks are each substantially circular, but each defines a gap so that each track forms with its associated ground plane a transmission line. The tracks are arranged coaxially about the shaft carrying the SAW device, one track and its associated ground plane being secured to the shaft whilst the other track and its associated ground plane is secured to a bearing through which the shaft passes. The tracks are separated by a thin sheet of dielectric material, or by a small air gap. One end of the track secured to the bearing is connected to the drive/measuring circuitry and one end of the track which is secured to the shaft is connected to the SAW device. The ends of the tracks opposite to their respective connections to the drive circuitry and the SAW device may be earthed or may be left open circuit.

The above described rotary signal coupler has a characteristic impedance which is substantially constant over a wide frequency range. However, the device has been found to be unsatisfactory in that both the phase variation and attenuation of signals passing though the coupler have been found to be dependent upon the relative rotational positions of the fixed and movable parts of the coupler. These phase variations and attenuation variations are highly undesirable since they significantly complicate the interpretation of the signals derived from the SAW device.

Published UK patent application GB 2 328 086A discloses a rotary signal coupler having a capacitor coupled across the gap between one or both of the tracks. This significantly reduces the problem of variable phase and variable attenuation.

However, although the couplers described in GB 2 328 086A operate satisfactorily on small diameter shafts (i.e. shafts having a diameter of 20mm or less), said couplers do not appear effective when used with larger diameter shafts. In particular, the coupler having stator and rotor tracks mounted in adjacent parallel planes (see Figure 1 of the accompanying drawings) has proved unsuitable for use with shaft diameters of 75mm or more. This arrangement is limited by the wavelength of the RF signal to be passed through the coupler. Furthermore, the diameters of the coupler stator and rotor tracks are dependent upon the velocity constant of the structure (wherein the velocity constant is the square root of a medium's dielectric constant). Although the aforementioned arrangement may be adapted in favour of larger diameter shafts by using low dielectric materials and by thus increasing the velocity constant, the improvements are small and do not allow satisfactory performance on shafts having a diameter of 75mm or more.

The present invention provides a rotary signal coupler comprising: a first substantially circular track secured to a first support; a second substantially circular track secured to a second support which is rotatable relative to the first support, the first and second tracks being coaxial with the axis of rotation of the rotatable second support and being adjacent each other to provide signal coupling therebetween; a first terminal connected to the first track; a second terminal connected to the second track; wherein one of said tracks has at least two gaps therein which form electrical discontinuities between separated track portions, the separated track portions being electrically connected to one another.

The above and further features and advantages of the present invention will become clear from the following description of preferred embodiments thereof given by way of example only, reference being had to the accompanying drawings wherein:

Figure 1 illustrates schematically a prior art rotary signal coupler disclosed in GB 2 329 086A;

Figure 2 illustrates schematically a rotor of a first embodiment of the present invention;

Figure 3 illustrates schematically the electric circuitry associated with the rotor of Figure 2; and

Figure 4 illustrates schematically the electric circuitry associated with a stator of the first embodiment.

Referring firstly to Figure 1, the illustrated prior art coupler 1 is shown schematically for providing signal coupling between a coax cable 2 and a coax cable 3. In the illustrated coupler, the coax cable 2 is connected to a driver/measuring circuit and the coax cable 3 is connected to a SAW device 4 mounted on a shaft 5. The coupling accordingly facilitates signal connection between the driver/measuring circuit and the SAW device for the purpose of measuring torque applied to the shaft 5.

The coupler 1 comprises a first part 6 which is secured to a fixed support by appropriate means and a second part 7 which is secured to the shaft 5. The parts 6,7 face each other and, in practice, are separated either by a small air gap or by a thin sheet of insulating material. The separation of the parts 6,7 has been exaggerated in the drawing so that the structure of the part 6 may be seen clearly. In practice, the parts 6,7 are likely to be separated by a small amount, typically 1 to 5mm.

The member 6 comprises a sheet 8 of insulating material which supports, on the side thereof remote from the part 7, a metal screen 9. Similarly, the part 7 comprises a sheet 10 of insulating material which supports, on the side thereof remote from the part 6, a metal screen 11. The screen 9 will, in many applications, be earthed, e.g. by way of connection to the screen 12 of the coax cable 2. The screen 11 will, in general, be electrically connected to the shaft 5, e.g. by way of the screen 13 of the coax cable 3. The shaft 5 will in general be earthed and accordingly the screens 9 and 11 are electrically connected.

The first part 6 has formed thereon two annular tracks 14,15. In a basic arrangement, only one track will be present, but in more complicated arrangements, several additional tracks may be present. Additional tracks may be used for signal coupling to additional devices. For example, if two separate SAW devices are secured to the shaft, two separate tracks would be used to provide coupling to them.

The tracks 14,15 may be of any suitable material, for example copper foil.

The tracks 14,15 are in the form of complete circles except for a gap 16 which forms an electrical discontinuity in each track. One end of the track 14 is connected to the core 17 of the coax cable 2. If an additional track, for example the track 15, is used, it will have associated therewith appropriate cable connections. For the purposes of illustration, only the outer track 14 is shown connected to a cable. In the illustrated coupler, the end of the track 14 opposite to the connection to the core 17 is connected to the screen 12 of the coaxial cable and to the screen 9. However, alternative arrangements may be desirable. For example, the end of the track remote from the connection to the coaxial cable may be left open circuit (except for the additional capacitor referred to below).

The face of the part 7 adjacent the part 6 has formed thereon tracks which mirror those of the part 6, as described above. One end of the outer track of the part 7 is connected to the core 18 of the coax cable 3, and the opposite end of that track is connected to the screen 13 of the coax cable 3 and to the screen 11 of the part 7. As with the track 14 of the part 6, said track of the part 7 may be left open circuit at the end opposite the connection to the core 18.

Each track 14 has connected across the gap 16 a capacitor. The capacitor may be a fixed capacitor or a variable capacitor permitting some adjustment to the capacitance of the circuit. The size of the capacitor will be selected so that the circuit is tuned to a slightly broader bandwidth than the frequency band expected to be encountered in use of the apparatus. The object is to tune the circuit to a small extent, but to leave the bandwidth broad enough to provide substantially constant coupling characteristics over the entire expected use frequency range. Typically, where the screens 9,11 are earthed, the supports 8,10 have a thickness of 1.5mm, the outer track 14 has an inside diameter of 40mm and a radial extent of 5mm, the value of the capacitor 19 will be approximately 30PF. This figure is similar to the capacitance

between the track and the screen 9,11. Such a device would typically have substantially uniform transmission characteristics over the frequency range 185- 215 MHz.

Each track of each pair of mating tracks may be furnished with a capacitor of substantially the same value. Further, although as illustrated the capacitor 19 is physically positioned on the parts 6,7 it is possible for the capacitor to be physically located remote from the part and electrically connected across the gap 16 by, for example, being electrically connected between the core and the screen of the associated coax cable.

Referring now to Figures 2 to 4, components of an improved rotary signal coupler are illustrated. Apart from the improvements discussed below, the improved coupler is identical to the prior art coupler shown in Figure 1 and, accordingly, like elements have been labelled with like reference numerals in the accompanying drawings.

In Figure 2, a rotor part 7 of an improved coupler is shown. For the purposes of clarity however, the SAW device 4 (attached to the shaft 5) and associated coax cable 13 are not illustrated. The rotor part 7 of the improved coupler differs from that of the prior art coupler shown in Figure 1 in that the tracks 102,104 (mounted on the planar surface of the part 7 hidden from view in Figure 2) are divided into two halves. Since the tracks 102,104 are provided on a hidden surface in Figure 2, said tracks 102,104 are illustrated in Figure 2 with broken lines.

It will be seen that the arrangement of the tracks 102,104 in two halves results in each track having two gaps 106,108. In the illustrated embodiment, the two halves of the outer track 102 are connected to one another by means of a coax cable 110 mounted on a semi-circular path on the planar surface of the part 7 visible in Figure 2. Connecting means (not shown in Figure 2) are provided for electrically connecting the coax cable 110 to the two halves of the outer track 102 through the thickness of the part 7. The coax cable 110 is connected at a first end thereof to a first end portion of a first semi-circular half of the outer track 102. A second end of the coax cable 110 (distal to said first end of the coax cable 110) is connected to a first end portion of a second semi-circular half of the outer track 102. The first end portions of the first and second semi-circular halves of the outer track 102 are diametrically opposed to one

another. For each of the semi-circular halves of the outer track 102, the second end portion (distal to the first end portion to which the coax cable 110 is connected) is connected through the thickness of the part 7 to the screen 11. These connections are indicated in the schematic electric circuit diagram of Figure 3 by reference numeral 112. As in the coupler of Figure 1, the screen 11 of the present embodiment is connected to earth via the screen 13 of the coax cable 3 (see Figure 3). Also, a variable capacitor 114 is connected to the second end portions of the two semi-circular halves of the outer track 102. The use of a capacitor is however optional.

In the illustrated embodiment, the inner track 104 is not connected to a SAW device and the two semi-circular halves thereof are not connected to one another. The inner track 104 and indeed further tracks may however be connected as described above with regard to the outer track 102. In this way, the coupler may be used with more than one SAW device.

As in the coupler of Figure 1, the improved coupler shown in the accompanying drawings incorporates a stator part 6 (see Figure 4) mounted to a bearing arrangement (not shown) in which the shaft 5 may rotate. However, the stator part of the improved coupler differs to the stator part of the prior art coupler in that the tracks 116 mounted thereon are provided in two semi-circular halves. These semi-circular halves are arranged as mirror images of the cooperating semi-circular track halves mounted on the rotor part 7 and are connected to one another by a coax cable 118 as described above with reference to the rotor part 7. Furthermore, the coax cable 118 is located on an opposite side of the stator part 6 to the track 116, the coax cable 118 and first end portions of the semi-circular track halves being electrically connected to one another through the thickness of the stator part 6 by appropriate means.

For each of the semi-circular halves of the track 116, a second end portion (distal to the first end portion to which the coax cable 118 is connected) is connected through the thickness of the part 6 to the screen 9. These connections are indicated in Figure 4 by reference numeral 120. As in the coupler of Figure 1, the screen 9 of the present embodiment is connected to earth via the screen 12 of the coax cable 2. A capacitor may be connected to the two track halves, although no capacitor is provided with illustrated stator part 6.

The present invention is not limited to the specific embodiment described above. Alternative arrangements and suitable materials will be apparent to a reader skilled in the art. For example, the tracks mounted on the stator and rotor parts may be provided with more than two gaps. The tracks may thus be divided into thirds or quarters or be otherwise divided. Indeed, one of the stator or rotor parts may be provided with tracks arranged in a conventional manner (for example, with a track having only a single gap).

CLAIMS:

1. A rotary signal coupler comprising: a first substantially circular track secured to a first support; a second substantially circular track secured to a second support which is rotatable relative to the first support, the first and second tracks being coaxial with the axis of rotation of the rotatable second support and being adjacent each other to provide signal coupling therebetween; a first terminal connected to the first track; a second terminal connected to the second track; wherein one of said tracks has at least two gaps therein which form electrical discontinuities between separated track portions, the separated track portions being electrically connected to one another.

2. A rotary signal coupler as claimed in claim 1, wherein the separated track portions are electrically connected to one another by means mounted on the associated support, the associated support being that suppot to which said track portions are secured.

3. A rotary signal coupler as claimed in claim 2, wherein said means for electrically connecting the separated track portions extends through the thickness of said associated support and locates on a side of said support opposite to that side of said support to which said track portions are secured.

4. A rotary signal coupler as claimed in claim 2 or 3, wherein said means for electrically connecting the separated track portions extends in a substantially semi-circular path.

5. A rotary signal coupler as claimed in any of the preceding claims, wherein said one of said tracks has two gaps which provide two separated track portions substantially semi-circular in shape.

6. A rotary signal coupler as claimed in claim 5, wherein a first end of means for electrically connecting the separated track portions is connected to a first end portion of one of said track portions and wherein a second end of said electrically connecting

means is connected to a first end portion of the other one of said track portions, the first end portions of the two track portions being diametrically opposite one another.

7. A rotary signal coupler as claimed in any of the preceding claims, wherein the separated track portions are electrically connected to one another by means comprising a coax cable.

8. A rotary signal coupler as claimed in any of the preceding claims, wherein the other of said tracks has at least two gaps therein which form electrical discontinuities between separated track portions, the separated track portions being electrically connected to one another.

9. A rotary signal coupler as claimed in claim 8, wherein the tracks are arranged as mirror images of one another, the first track comprising separated track portions electrically connected to one another in the same way as the separated track portions of the second track are electrically connected to one another.

10. A rotary signal coupler substantially as hereinbefore described with reference to the accompanying drawings.

Fig.1.
PRIOR ART

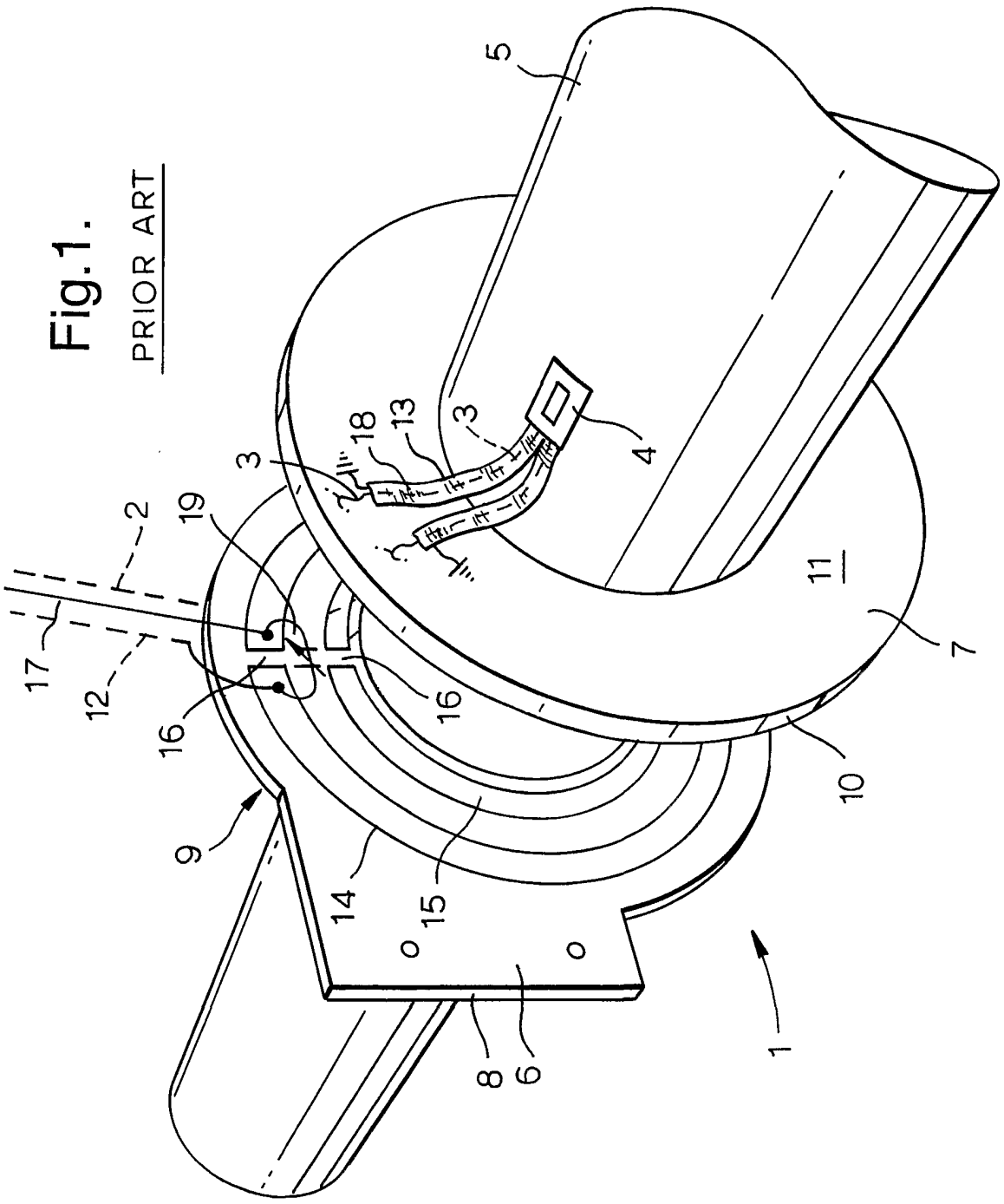


Fig.2.

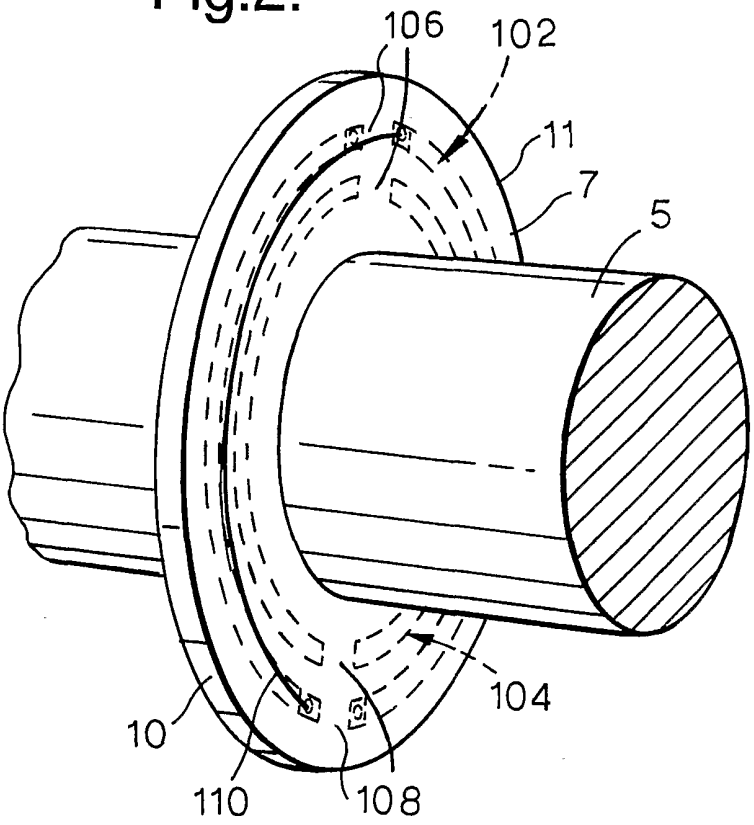

106
102
11
7
5
104
10
110
108

Fig.3.

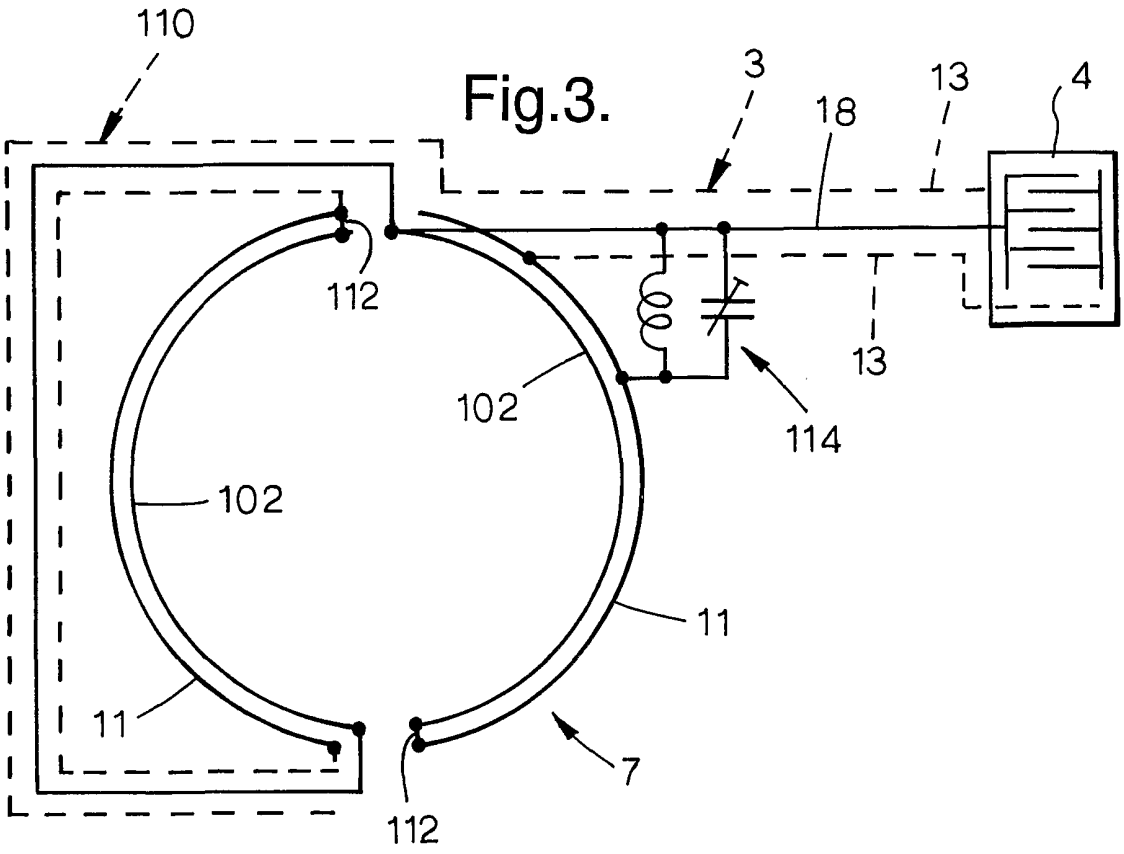

110
3
18
13
4
112
102
13
114
102
11
11
7
112

Fig.4.

