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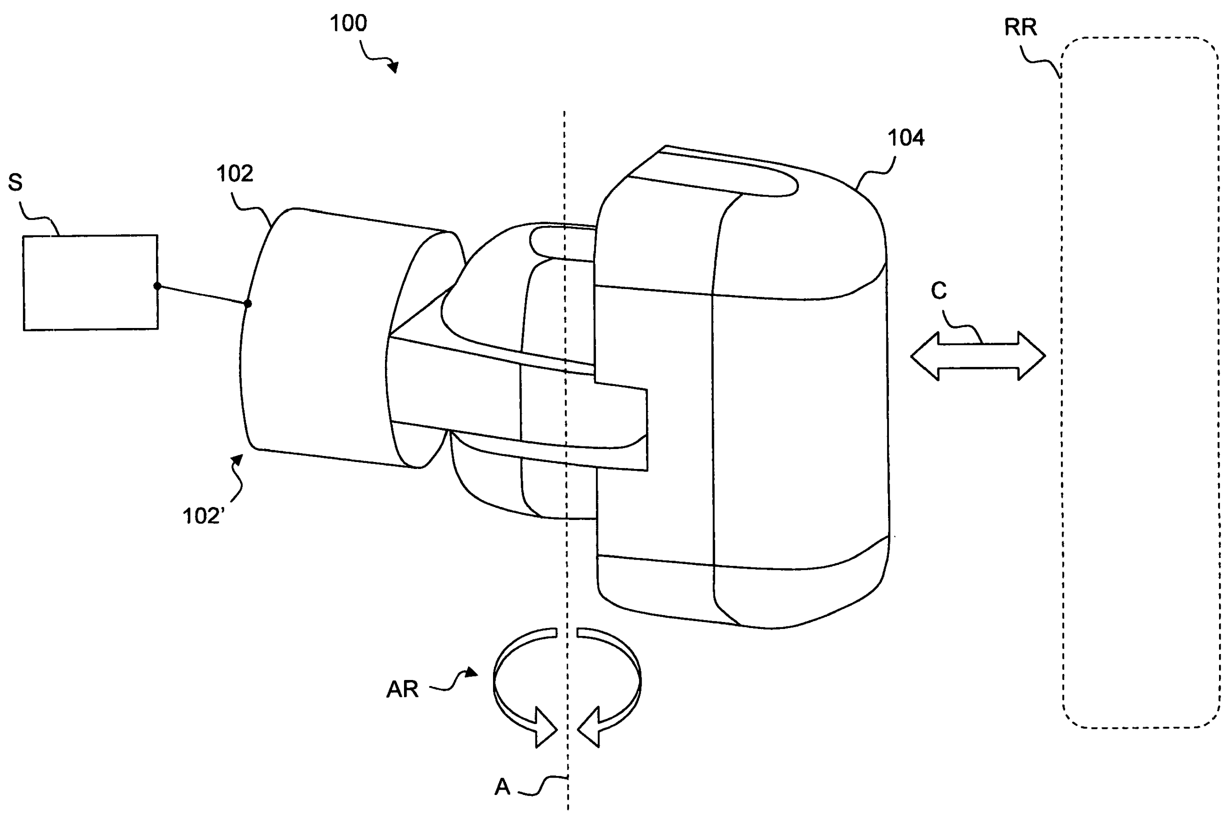
(54) **Rotatable coupling structure for radio frequency signals**

(57) The invention relates to a coupling structure (100) for radio frequency, RF, signals, wherein said coupling structure (100) comprises a connecting element (102) comprising a connecting section (102') for electrically and/or mechanically connecting said coupling structure (100) to a source (S) and/or sink of RF signals, said coupling structure (100) further comprising a coupling element (104) that is electrically connected to said connecting element (102), wherein said coupling element (104) is rotatably attached to said connecting element (102).

Fig. 1



EP 2 544 296 A1

Description

Field of the invention

[0001] The invention relates to a coupling structure for radio frequency, RF, signals.

Background

[0002] Similar coupling structures are e.g. used in RF filter assemblies for capacitively coupling neighboring cavity resonators.

Summary

[0003] It is an object of the present invention to provide an improved coupling structure for RF signals that enables efficient tuning of RF filters or other components comprising said coupling structure.

[0004] According to the present invention, this objective is achieved by said coupling structure comprising a connecting element comprising a connecting section for electrically and/or mechanically connecting said coupling structure to a source and/or sink of RF signals, said coupling structure further comprising a coupling element that is electrically connected to said connecting element, wherein said coupling element is rotatably attached to said connecting element.

[0005] Rotatably attaching said coupling element to said connecting element advantageously enables to provide a variable capacitive coupling, particularly capacitive coupling, between said coupling structure and a further element such as e.g. a cavity resonator, particularly a TEM-mode coaxial cavity resonator, arranged nearby the coupling structure. Thus, e.g. a coupling strength of a capacitive coupling between an RF source connected to said connecting element and a neighboring resonator element may be adjusted by varying the distance between the coupling element and the resonator element, in particular a resonator rod. Advantageously, the distance between the neighboring elements may easily be varied by modifying the angle of rotation of the coupling element with respect to the connecting element, the connecting element usually being fixedly attached to the RF source and/or sink or an RF connector element or the like.

[0006] According to an advantageous embodiment, said coupling element is hinged to said connecting element, which offers a particularly flexible and yet stable arrangement.

[0007] According to a further embodiment, said coupling element comprises a basically cylindrical shape which enables to reduce manufacturing costs.

[0008] According to a further embodiment, a cross-section of said coupling element at least partly comprises an elliptical shape or a shape like a rounded rectangle. Especially, the coupling element is suitably shaped so as to avoid sharp edges thereby avoiding strong local electric (E)-fields in the sense of peak power handling properties of the coupling structure.

[0009] According to a further embodiment, driving means for rotating said coupling element with respect to said connecting element are provided. Said driving means may e.g. comprise actuator means for automatically, i.e. without manual action, tuning said coupling structure.

[0010] However, according to a further preferred embodiment, said driving means comprise a rod which is attached to said coupling element, said rod preferably comprising electrically non-conductive material such as ceramics and/or polytetrafluoroethylene (PTFE).

[0011] According to a further embodiment, said connecting element comprises a hinge section having two substantially flat opposing surface sections, and said coupling element is rotatably attached to said hinge section.

[0012] A further solution to the objective of the present invention is given by a filter for radio frequency, RF, signals comprising at least one coupling structure according to the embodiments.

[0013] According to a further embodiment, said filter comprises an input port for receiving RF signals to be filtered, wherein said at least one coupling structure is arranged at said input port. Thus, advantageously, the strength of the coupling between the input port and a first resonator of the RF filter may be adjusted.

[0014] According to a further embodiment, said connecting element of the coupling structure is connected to an inner conductor of said input port. E.g., the input port may comprise a coaxial RF connector for interfacing with an RF cable or any other RF source. The inner conductor of the RF connector may advantageously be connected mechanically and/or at least electrically with the connecting element of the coupling structure according to the embodiments to provide adjustable coupling of an RF signal supplied by said RF source to further components of said filter, e.g. cavity resonators.

[0015] Further advantageous features of the invention are defined and are described in the following detailed description of the invention.

Brief description of the figures

[0016] The embodiments of the invention will become apparent in the following detailed description and will be illustrated by accompanying figures given by way of non-limiting illustrations, wherein:

Figure 1 schematically depicts a perspective view of a coupling structure according to an embodiment,

Figure 2 schematically depicts a side view of a coupling structure according to an embodiment,

Figure 3 schematically depicts a top view of a filter for radio frequency signals according to an embodiment,

Figure 4 depicts a simplified equivalent circuit of a coupling structure according to an embodiment and an associated resonator,

Figure 5a schematically depicts a side view of a coupling structure according to a further embodiment,

Figure 5b schematically depicts a top view of the coupling structure according to Figure 5a in a first operational state, and

Figure 5c schematically depicts a top view of the coupling structure according to Figure 5a in a second operational state.

Description of the embodiments

[0017] Figure 1 schematically depicts a perspective view of a coupling structure 100 according to an embodiment.

[0018] The coupling structure 100 is used for establishing a variable, i.e. adjustable, particularly capacitive, coupling C between a source S of RF signals and a component RR of an RF filter (not shown) which is used to filter the RF signal provided by said RF source S.

[0019] For this purpose, the coupling structure 100 comprises a connecting element 102 which is connected to the source S with its connecting section 102' to receive said RF signal. Fig. 1 only schematically indicates a connection between the connecting element 102 and the RF signal source S by means of a single line. However, as will be appreciated by those skilled in the art, e.g. a coaxial transmission line (not shown) having an inner conductor and an outer conductor may be used to establish a suitable RF signal connection between the RF signal source S and the connecting element 102. In this case, the connecting element 102 would e.g. be connected in an electrically conductive manner to the inner conductor of the coaxial transmission line.

[0020] The coupling structure 100 also comprises a coupling element 104 which operates as a coupling probe and which is rotatably attached in an electrically conductive manner to said connecting element 102, and which is used for establishing the capacitive coupling C with the component RR. Presently, the component RR may e.g. represent a resonator rod of a resonator cavity of said RF filter.

[0021] By varying the angle of rotation of said coupling element 104 around an axis A, as depicted in Fig. 1 by the arrows AR, with respect to the connecting element 102, the distance between the coupling element 104 and the resonator rod RR and also the orientation of the coupling element 104 with respect to the resonator rod RR may be varied thus influencing the strength of the capacitive coupling C.

[0022] Figure 2 schematically depicts a side view of a coupling structure 100 according to an embodiment.

[0023] As can be seen from Fig. 2, the connecting element 102 comprises a hinge section 102a having two substantially flat opposing surface sections 102a', 102a'', and said coupling element 104 is rotatably attached to said hinge section 102a.

[0024] Preferably, driving means 106 are provided for rotating said coupling element 104 with respect to said connecting element 102. According to a particularly preferred embodiment, said driving means 106 comprise a non-metallic rod 106a which is attached to said coupling element 104.

[0025] Thus, by rotating the rod 106a, the position of the coupling element 104 may be adjusted.

[0026] A further solution to the objective of the present invention is given by a filter for radio frequency, RF, signals comprising at least one coupling structure according to the embodiments.

[0027] Figure 3 shows schematically in a block diagram and a top view a filter FL according to a preferred embodiment of the invention. The detailed structure of the filter FL is not critical, and as can be understood by those skilled in the art, the detailed structure of the filter FL may vary without departing from the scope of the invention.

[0028] The filter FL may be a bandpass filter for radio frequency signals of a broadcasting service or may be applied in a transmission path of a base station of a network of a broadcasting transmission provider. The filter FL may be for example a high-power radio broadcasting filter adapted to a frequency band with a frequency tuning range between 470 MHz and 860 MHz.

[0029] Alternatively, the filter FL may be applied in a transmission and/or reception path of a base station of a mobile radio network using a radio access technology such as GSM/GPRS (GSM = Global System for Mobile Communication, GPRS = General Packet Radio Service), UMTS (UMTS = Universal Mobile Telecommunication Systems), or LTE (LTE = Long Term Evolution). Therefore, the filter FL may be for example adapted to 900 MHz or 1800 MHz frequency bands of GSM or to frequency bands specified for UMTS, WiMAX (WiMAX = Worldwide Interoperability for Microwave Access), and/or LTE.

[0030] The filter FL may comprise a first cavity resonator RC1, a second cavity resonator RC2, a third cavity resonator RC3, a fourth cavity resonator RC4, a fifth cavity resonator RC5 and a sixth cavity resonator RC6 arranged in (but not limited to) a U-shaped order with a U-shaped resonator path as indicated in Figure 3 by an arrow AR'. The cavity resonators RC1 to RC6 may be coaxial transverse electromagnetic wave mode resonators and may have identical geometrical dimensions.

[0031] Alternatively, the filter FL may comprise more or less than six cavity resonators.

[0032] In a further alternative, the cavity resonators may be arranged in a linear or straight form or in any other form. In even further alternatives, the cavity resonators may be arranged in an S-shaped order, or an arrangement of the cavity resonators may comprise a combination of cavity resonators in a U-shaped order and of further cavity resonators in an S-shaped order.

[0033] The filter FL comprises a first port PORT1 for coupling the radio frequency signals to be filtered into the filter FL and comprises a second port PORT2 for coupling out filtered radio frequency signals from the filter FL.

[0034] The ports PORT1, PORT2 may be for example coaxial ports with a central inner and an outer conductor. An inner conductor IC of the input port PORT1 is indicated in Fig. 3 by a dashed rectangle.

[0035] Openings within a first outer wall OW1 of a housing of the filter FL between the first port PORT1 and the first cavity resonator RC1 and between the second port PORT2 and the sixth cavity resonator RC6 are not shown for simplification.

[0036] The housing of the filter FL is shown in Figure 3 without a cover plate to be able to see the interior parts of the filter FL.

[0037] The filter's housing comprises a base plate BP, the first outer wall OW1, a second outer wall OW2, a third outer wall OW3, a fourth outer wall OW4. Moreover, the filter FL comprises a first inner separating wall ISP1 as well as further inner separating walls which are not assigned a reference numeral in Figure 3 for the sake of clarity. Resonator rods RR1, RR2, RR3, RR4, RR5, RR6 are located centrally within the resonator cavities RC1 to RC6 and are extending upwards from the base plate BP, i.e. perpendicularly upwards from the drawing plane of Figure 3.

[0038] The housing of the filter FL is used as an outer conductor and the resonator rods RR1 to RR6 are used as inner conductors. The base plate BP, the outer walls OW1 to OW4, the inner separating walls and the cover plate (not shown in Figure 3) form separate hollow spaces, for the resonator cavities RC1 to RC6.

[0039] The filter FL further comprises a first coupling loop STR1 in a first opening of the second inner separating wall between the first cavity resonator RC1 and the second cavity resonator RC2, a second coupling loop STR2 in an opening OP3 of the inner separating wall between the second cavity resonator RC2 and the third cavity resonator RC3, a third coupling loop STR3 in an opening of the fourth inner separating wall between the third cavity resonator RC3 and the fourth cavity resonator RC4, a fourth coupling loop STR4 in an opening of the fifth inner separating wall between the fourth cavity resonator RC4 and the fifth cavity resonator RC5 and a fifth coupling loop STR5 in an opening of the sixth inner separating wall between the fifth cavity resonator RC5 and the sixth cavity resonator RC6.

[0040] The coupling loops STR1 to STR5 are used for direct inductive electromagnetic couplings between adjacent cavity resonators in a direction of the arrow AR and have preferably externally adjustable immersion depths.

[0041] In a preferred embodiment, the first and the second coupling loops STR1, STR2 are located with a first distance D1 to the fourth outer wall OW4 of the filter FL and with a second distance D2 to the first inner separating plate ISP1, and the first distance D1 is smaller than the second distance D2. Equally, the third and the fourth coupling loops STR3, ST4 are located with the first distance D1 (not shown) to the second outer wall OW2 of the filter FL and with the second distance D2 (not shown) to the first inner separating plate ISP1.

[0042] In a further preferred embodiment of the invention as shown in Figure 3, the second distance D2 is in a range between a threefold and fourfold of the first distance D1.

[0043] A filter for RF signals exhibits an electromagnetic coupling between adjacent cavity resonators in a direction of the resonator path such as shown by the arrow AR in Figure 3. This type of electromagnetic filter resonator coupling is called direct coupling or adjacent coupling between the cavity resonator pairs RC1/RC2, RC2/RC3, RC3/RC4, RC4/RC5, RC5/RC6. A specific bandwidth of the passband can be adjusted according to a specific filter mask for fulfilling the spectral requirements by adjusting the direct coupling between the cavity resonator pairs RC1/RC2, RC2/RC3, RC3/RC4, RC4/RC5, RC5/RC6.

[0044] The filter usually also exhibits a further electromagnetic coupling between cavity resonators, which are not adjacent in the direction AR of the resonator path. This further type of electromagnetic filter resonator coupling is referred to as cross coupling. Due to the U-shape of the resonator path of the filter FL exemplarily shown in Figure 3, cross couplings may be established by providing suitable coupling means EL1 between the following pairs of resonator cavities: RC1/RC6, RC2/RC5 or between other non-adjacent resonators (e.g., for filter configurations with more than six resonator cavities).

[0045] Cross coupling can be used to include transmission zeros or notches in monotonous sloping filter attenuation curves (responses) besides a (transmission) passband of the bandpass filter being symmetrically arranged according to a centre frequency of the passband. The cross coupling between two cavity resonators not adjacent in the direction AR' of the resonator path determines a frequency position and a symmetry of notches of the filter characteristic.

[0046] Such application is known to a person skilled in the art and is therefore not further explained in the following.

[0047] Advantageously, the filter FL depicted by Fig. 3 comprises at least one coupling structure 100 (Fig. 1) according to the embodiments.

[0048] Presently, a first coupling structure 100a is arranged at the input port PORT1, and a second coupling structure 100b is arranged at the output port PORT2 of the filter FL. Both coupling structures 100a, 100b may e.g. comprise a structure identical or similar to the configuration 100 depicted by Fig. 1, 2.

[0049] The first coupling structure 100a advantageously enables to adjust the coupling strength between the input port PORT1 and the first resonator cavity RC1 of the filter FL, while the second coupling structure 100b advantageously enables to adjust the coupling strength between the sixth resonator cavity RC6 and the output port PORT2 of the filter FL.

[0050] The structures 100a, 100b may e.g. provide non-metallic tuning rods 106 (Fig. 2) which protrude through respective openings in the cover plate of the filter FL to facilitate adjusting the respective coupling parameters without requiring to open the casing of the filter FL.

[0051] According to a further embodiment, the connecting element 102 (Fig. 1) of the coupling structure 100a (Fig. 3) may be connected to the inner conductor IC of the input port PORT1, e.g. by soldering or by establishing a detachable connection. Alternatively, the connecting element 102 may also be an integral part of the inner conductor IC.

[0052] By employing the coupling structures 100, 100a, 100b, the coupling between the input port PORT1 and the output port PORT2 of the filter FL to the input and output resonators RR1, RR6 may be adjusted via the rotationally movable coupling element 104. Thus, the electromagnetic energy from the input connector IC is fed via said coupling element 104 to the first resonator RR1 via electric field coupling and vice versa from the last resonator RR6 to the output connector PORT2.

[0053] It is to be noted that the inventive principle directed to a coupling structure 100 (Fig. 1) with a rotatably attached coupling element 104 may generally be applied to any RF signal processing apparatus where a, preferably adjustable, capacitive coupling is desired.

[0054] Especially, although the embodiment of the filter FL described above with reference to Fig. 3 represents one specific field of application of the coupling structure 100, 100a, 100b according to the embodiments, the present invention is not limited to such application. For instance, instead of cavity filters as depicted by Fig. 3, waveguide cavity filters, which typically use empty metallic cavities as resonators and which are insofar very different from the filter FL shown in Fig. 3, may also be equipped with one or more coupling structures according to the embodiments.

[0055] Further, the inventive principle directed to a coupling structure 100 (Fig. 1) with a rotatably attached coupling element 104 is not even limited to being applied in RF filters, but may generally be used in any RF signal processing configuration where a, preferably adjustable, capacitive coupling is desired.

[0056] An equivalent circuit of an input section of a bandpass filter using a variable capacitive coupling according to the embodiments is depicted by Fig. 4.

[0057] A first, variable capacitor C1 represents the adjustable coupling capacitance as enabled by the coupling structure 100 according to the embodiments, also cf. the coupling link C symbolically depicted by Fig. 1. The elements C2, L1, C3, L2 represent respective capacitive and inductive elements of resonant circuits of the bandpass filter in the sense of equivalence between the real filter and a lumped element circuit.

[0058] Figure 5a schematically depicts a side view of a coaxial resonator using a coupling structure 100c according to a further embodiment. The coupling structure 100c is integrated into a cavity resonator CR and enables a primarily capacitive coupling between a resonator rod RR of said cavity resonator CR and an inner conductor IC of an RF supply line. More precisely, the inner conductor IC of the RF supply line at the input connector PORT1 is connected to the connecting element 102, also cf. Fig. 1, of the coupling structure 100c, and the coupling element 104 is rotatably attached to said connecting element 102 also establishing an electrically conductive connection between the connecting element 102 and the rotatable coupling element 104. Rotational movement of the coupling element 104 is effected by turning a non-metallic rod 106a, an axial end section 106a' of which protrudes through an opening (not shown) of a wall of the cavity resonator CR. Thus, a person or an automated drive mechanism may rotate the non-metallic rod 106a during adjustment and tuning of the cavity resonator CR.

[0059] Figure 5b schematically depicts a top view of the coupling structure 100c according to Figure 5a in a first (operational) adjusted state, wherein a longitudinal axis of the coupling element 104, cf. the dashed line, defines a first rotational angle $\alpha 1$ with a side wall of the cavity resonator CR, whereby a first capacitive coupling setting is established with the resonator rod RR.

[0060] After rotating the coupling element 104 of Figure 5b in a clockwise direction by the rotational angle $\alpha 1$, e.g. by means of driving the non-metallic rod 106a (Figure 5a), the second adjustment state as depicted by Figure 5c is attained. In this second state, the longitudinal axis of the coupling element 104 is substantially parallel to the side wall of the cavity resonator CR, whereby a second capacitive coupling setting is established with the resonator rod RR, said second capacitive coupling setting being different from the first capacitive coupling setting of Figure 5b due to an increased distance between the elements 104, RR and the altered overall geometry within the cavity resonator CR.

[0061] The adjustment state of the coupling element 104 as given in Fig. 5c may also advantageously involve a shunt capacitance between the coupling element 104 to the neighboring resonator cavity wall. This shunt capacitance further reduces the overall coupling and thereby increases the adjustment range provided by the coupling structure according to the embodiments. I.e., a minimum coupling is achieved by the adjustment state according to Fig. 5c, whereas a maximum coupling may be achieved by selecting a rotational angle $\alpha 1 = 90°$ (cf. Fig. 5a for the definition of the rotational angle $\alpha 1$). The adjustment range is an important parameter for tunable filters, especially for high-power broadcast transmitter filters.

[0062] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. Coupling structure (100) for radio frequency, RF, signals, wherein said coupling structure (100) comprises a connecting element (102) comprising a connecting section (102') for electrically and/or mechanically connecting said coupling structure (100) to a source (S) and/or sink of RF signals, said coupling structure (100) further comprising a coupling element (104) that is electrically connected to said connecting element (102), wherein said coupling element (104) is rotatably attached to said connecting element (102).

2. Coupling structure (100) according to claim 1, wherein said coupling element (104) is hinged to said connecting element (102).

3. Coupling structure (100) according to one of the preceding claims, wherein said coupling element (104) comprises a basically cylindrical shape.

4. Coupling structure (100) according to claim 3, wherein a cross-section of said coupling element (104) at least partly comprises an elliptical shape or a shape like a rounded rectangle.

5. Coupling structure (100) according to one of the preceding claims, wherein driving means (106) for rotating said coupling element (104) with respect to said connecting element (102) are provided.

6. Coupling structure (100) according to claim 5, wherein said driving means (106) comprise a rod (106a) which is attached to said coupling element (104).

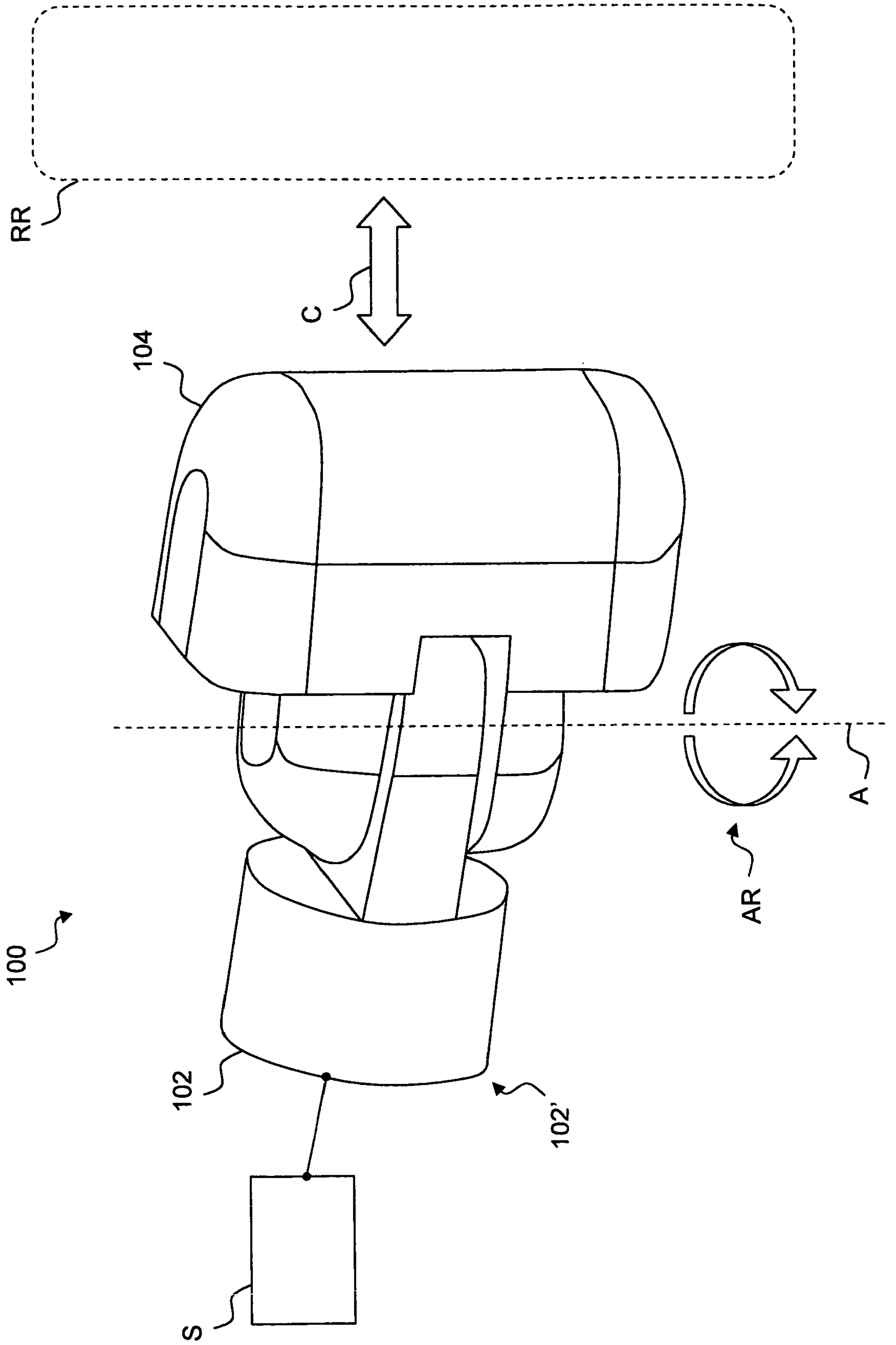
7. Coupling structure (100) according to one of the preceding claims, wherein said connecting element (102) comprises a hinge section (102a) having two substantially flat opposing surface sections (102a', 102a''), and wherein said coupling element (104) is rotatably attached to said hinge section (102a).

8. Filter (FL) for radio frequency, RF, signals comprising at least one coupling structure (100a, 100b) according to one of the preceding claims.

9. Filter (FL) according to claim 8, wherein said filter (FL) comprises an input port (PORT1) for receiving RF signals to be filtered, wherein said at least one coupling structure (100a) is arranged at said input port (PORT1).

10. Filter (FL) according to claim 9, wherein said connecting element (102) of the coupling structure (100a) is connected to an inner conductor (IC) of said input port (PORT1).

Fig. 1



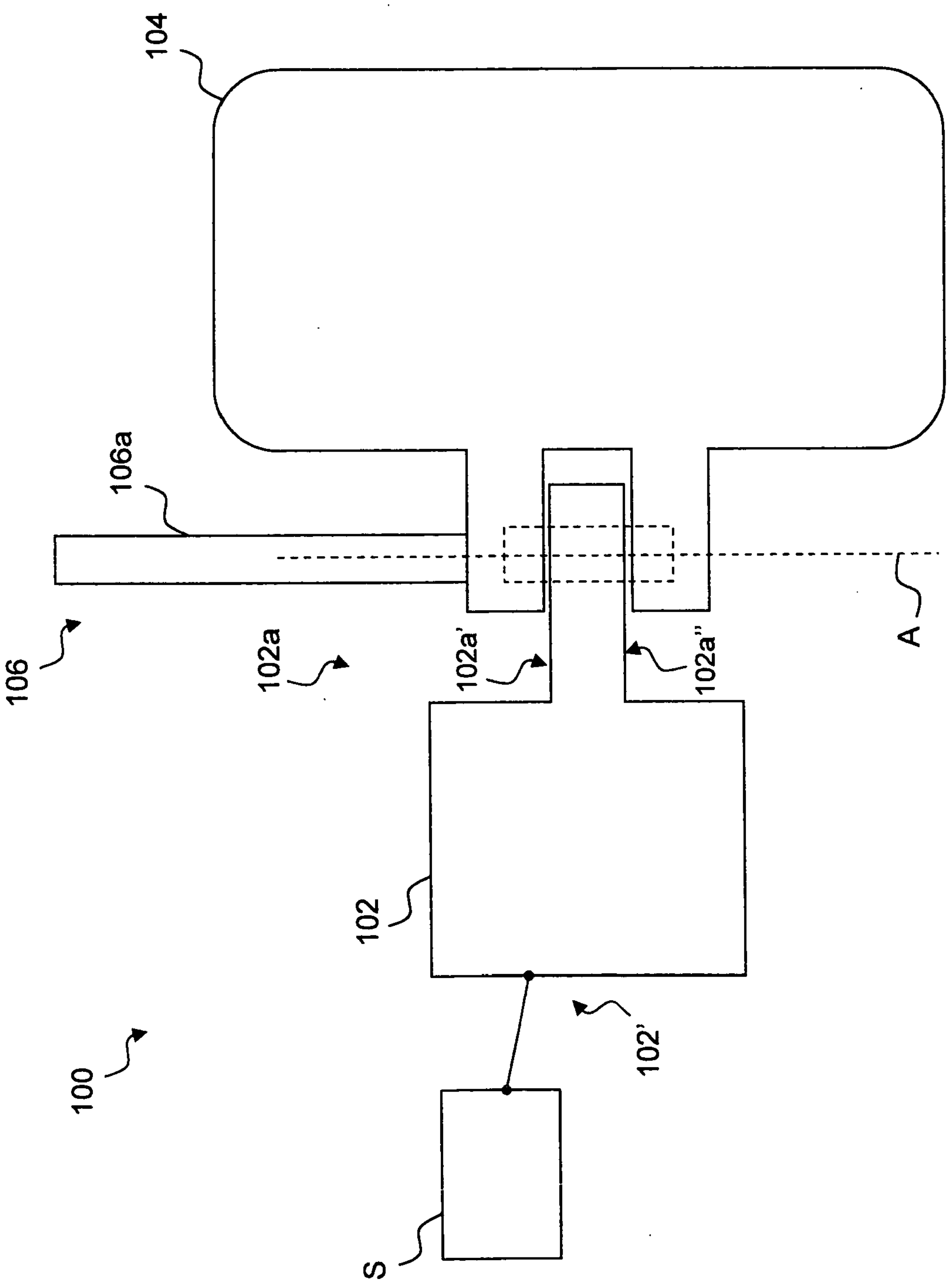


Fig. 2

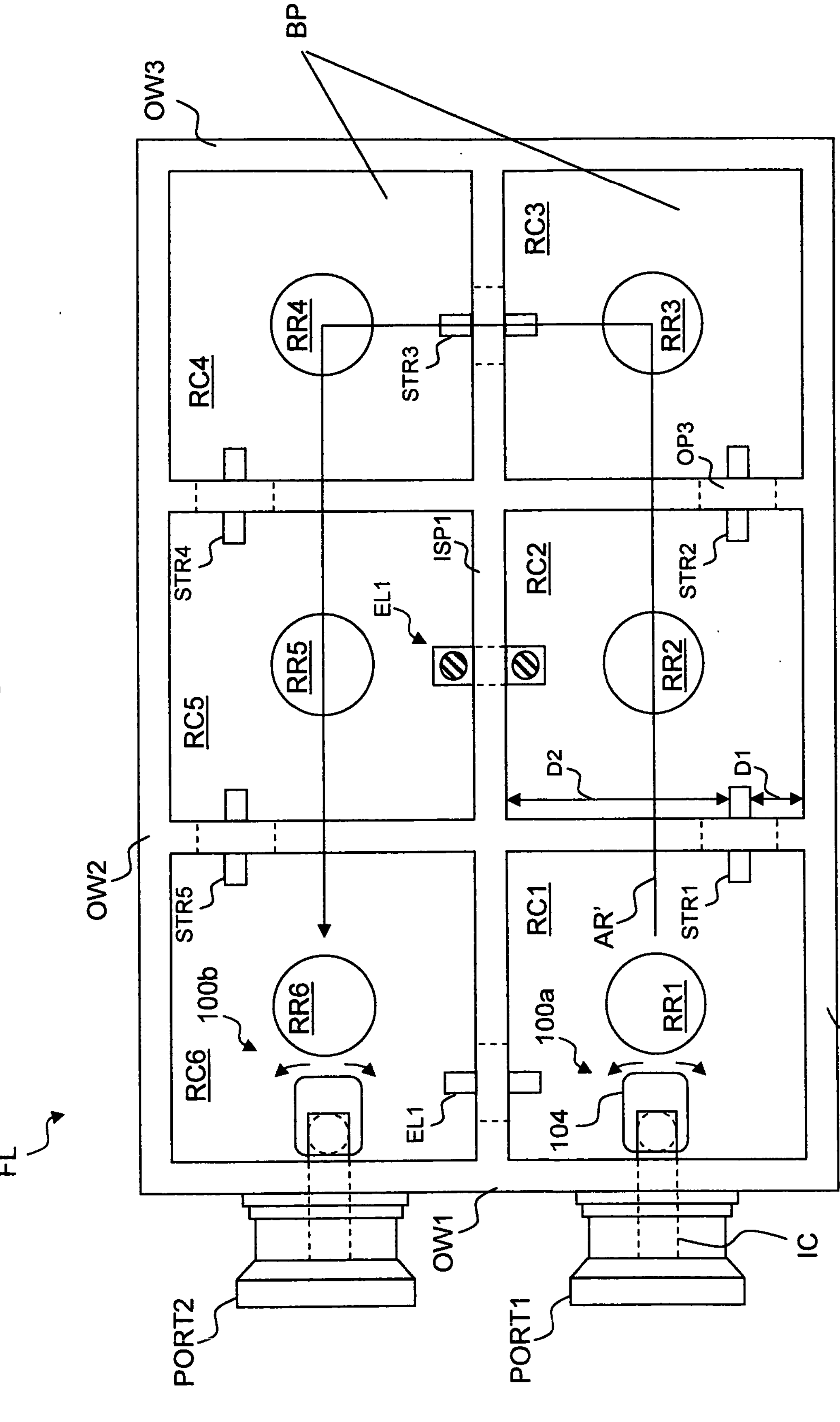

BP
OW3
RC4
RR4
RC3
RR3
STR3
OP3
STR4
ISP1
EL1
RC5
RR5
RC2
RR2
STR2
D2
D1
OW2
STR5
RC1
AR'
STR1
100b
RR6
100a
RR1
RC6
EL1
104
OW4
FL
OW1
IC
PORT2
PORT1

Fig. 3

Fig. 4

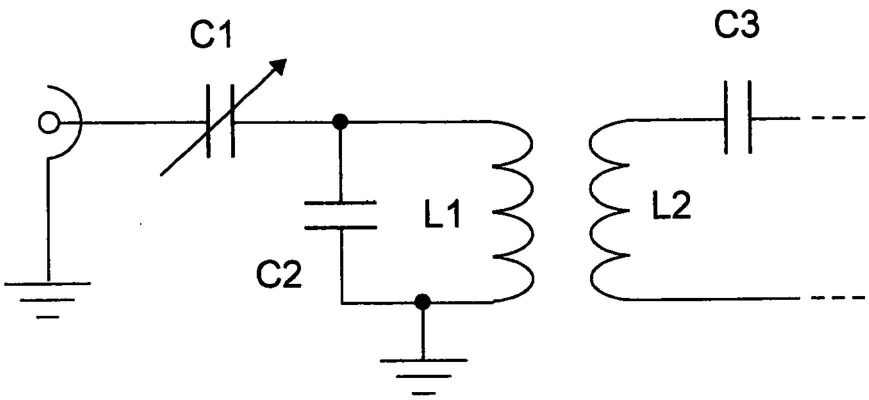


Fig. 5a

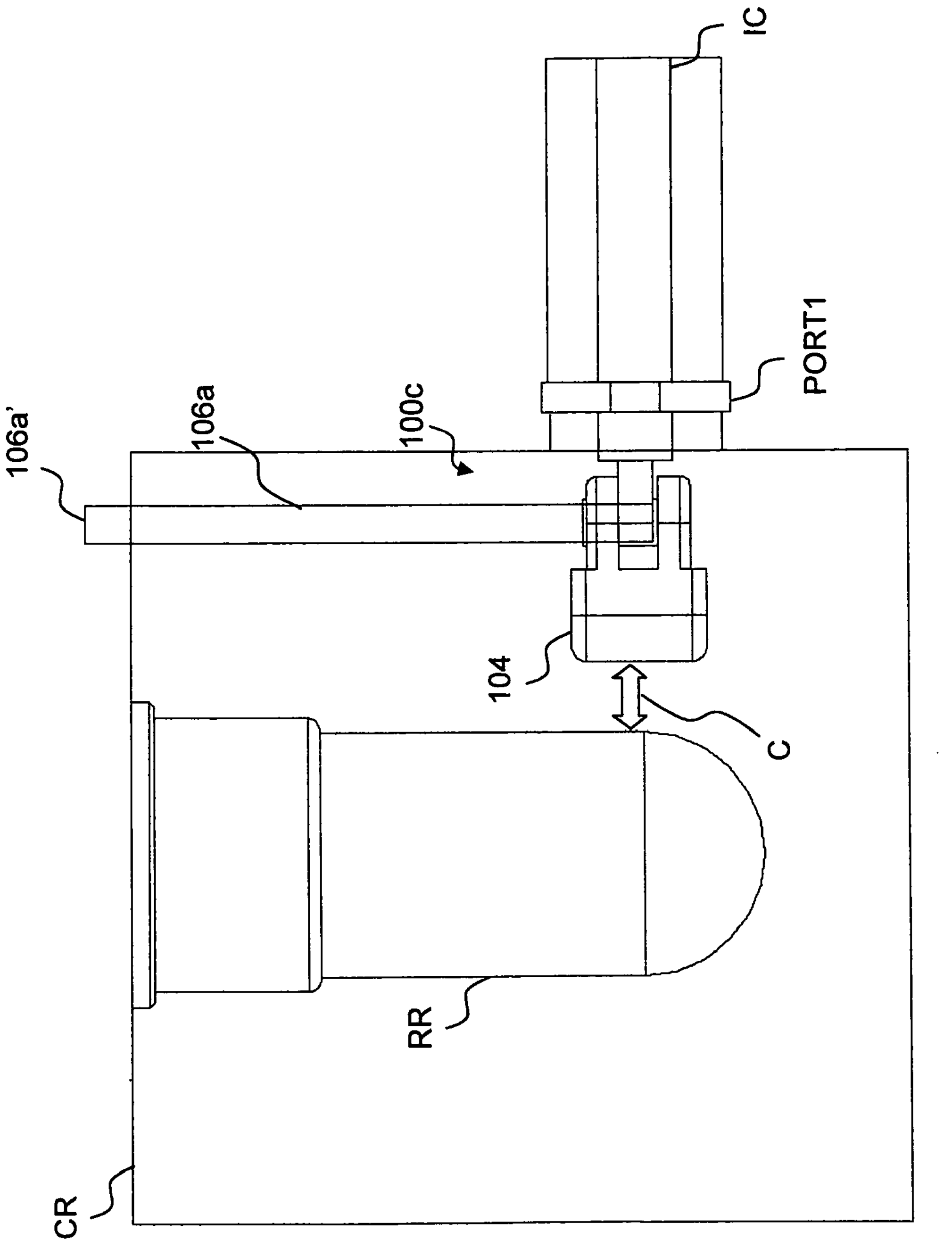


Fig. 5c

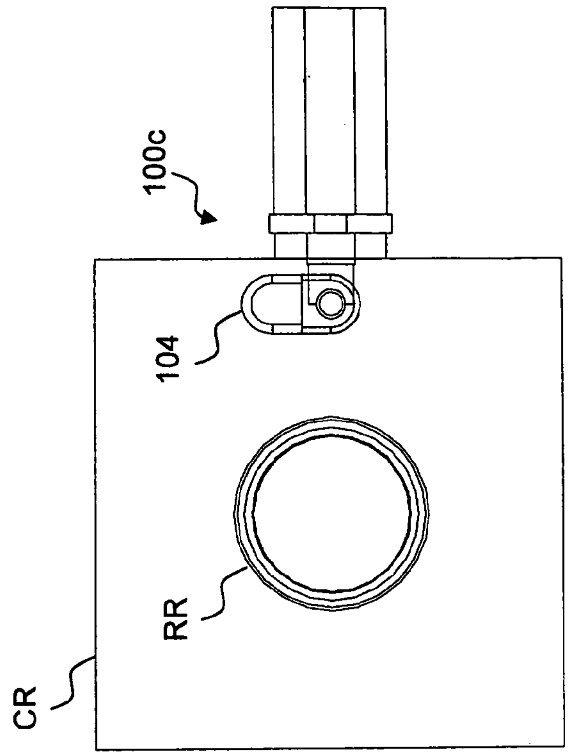
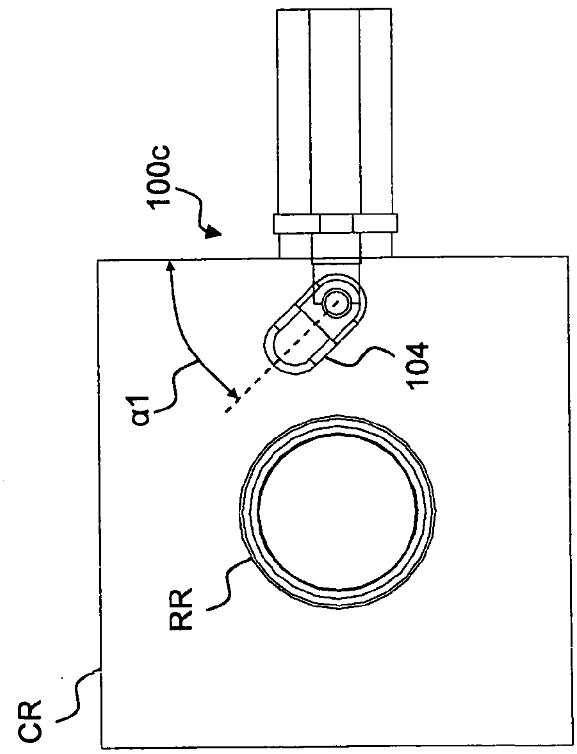


Fig. 5b



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EUROPEAN SEARCH REPORT

Application Number
EP 11 29 0313

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP H01 63207 U (*) 24 April 1989 (1989-04-24) * figures 1, 2 * -----	1-4,7-10	INV. H01P1/06 H01P1/205 H01P1/207
X	US 4 746 883 A (SAUVAGE MARC [FR] ET AL) 24 May 1988 (1988-05-24) * column 2, line 21 - line 63; figures 2-4 * -----	1,3-6, 8-10	
X	US 2 753 531 A (BUTLER JESSE L) 3 July 1956 (1956-07-03) * column 2, line 43 - column 3, line 8; figures 1-3 * -----	1-4,7	

TECHNICAL FIELDS SEARCHED (IPC)

H01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	9 January 2012	La Casta Muñoa, S

CATEGORY OF CITED DOCUMENTS

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