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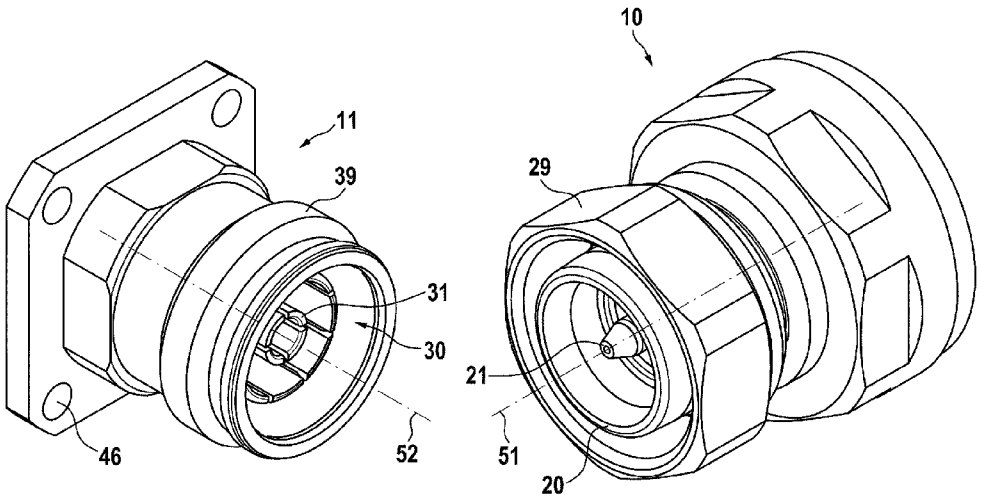
(54) **Title:** LOW PASSIVE INTERMODULATION RF CONNECTOR

Fig. 1



(57) **Abstract:** A coaxial connector comprises a center conductor and an outer conductor coaxial to the center conductor. The outer conductor has a cylindrical shape with slits forming a plurality of spring loaded contact elements. The connector further has a base for mounting the coaxial connector and an outer housing. To improve passive intermodulation characteristics, the base, the slotted outer conductor and the outer housing are made of one piece.

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[Continued on next page]

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Low Passive Intermodulation RF Connector

Field of the invention

The invention relates to a coaxial connector for radio frequencies (RF). A socket part having a low Passive Intermodulation (PIM) outer conductor and may be mated with a plug part.

Description of the related art

US 9,236,694 B2 discloses a coaxial connector system designed for low passive intermodulation. A plug connector has a spring-loaded outer connector for contacting the solid side wall of a socket connector. Due to a precision contact design and high contacting forces between the plug connector and the second connector, a low passive intermodulation is achieved.

JP 2010257678 A discloses a simple coaxial connector housing being one part with a mounting flange.

CA 2 432 051 A1 discloses a connector having an outer mounting thread.

DE 84 24 348 U1 discloses a coaxial connector having soldering openings for the outer conductor.

US 2009/280682 A1 discloses a RF connector with a mounting flange at the outer connector.

WO 2015/192382 A1 discloses a RF connector being part of a complex housing.

DE 18 13 161 U discloses a further RF connector with slotted outer conductor.

Summary of the invention

The problem to be solved by the invention is to provide a socket connector having a spring-loaded outer conductor while improving passive intermodulation characteristics.

Solutions of the problem are described in the independent claims. The dependent claims relate to further improvements of the invention.

In general, a coaxial plug connector and a coaxial socket connector each have a housing, a center conductor and an outer conductor. The center conductors define by their centers a center axis of the connectors. The outer conductors are arranged coaxially around the center conductors and hold the center conductors by insulators. The housing may be a part of the outer conductor.

Herein, for simplicity it is distinguished between a plug connector and a socket connector. This naming has no influence on the embodiments as long as the essential features are provided.

A coaxial plug connector has an outer conductor, which fits, into a socket of the socket connector. A center conductor at the plug connector contacts and preferably fits into a center conductor of the socket connector. There is preferably at least one means for mechanically fastening the plug connector to the socket connector.

According to a first embodiment, the coaxial socket connector has an outer conductor with a plurality of parallel slits extending from the plug connector facing side and dividing the outer conductor into a plurality of spring loaded contact elements. These spring-loaded contact elements fit into the inner contour of the coaxial plug connector, which preferably comprises cylindrical and conical sections. Preferably, the spring-loaded contact elements are oriented such, that they apply force in radial direction outwards of the center when mated.

The coaxial socket connector has a base which may be used for mounting the connector and which preferably forms the ground connection of the connector. The base may be mounted to any device like a metal plate, a housing or similar. Preferably, the base comprises a flange, most preferably a rectangular flange. The flange may be held by at least one screw.

Alternatively, the base may comprise a bearing surface. The outer housing may comprise an outer thread for holding a nut which may be tightened to hold any device like a metal plate, a housing or similar between the bearing surface and the nut. There may be a sealing close to the bearing surface.

The base may also have a cylindrical shape, preferably having a thread, such that it may be held in a hole and locked by a nut.

The outer conductor comprising a plurality of spring loaded contact elements is one part with the base. Here, the spring loaded contact elements are not pressed forming a press fit nor soldered nor welded into the base. Due to this monolithic embodiment, there is no electrical connection in the current path of the outer conductor between two parts, which may have a thin oxide layer generating PIM. Therefore, PIM is further minimized.

The connector may have a mechanical contact surface at a right angle to the center axis and distant from the spring loaded contact elements.

An outer housing may be provided at the base forming one part with the base.

It is further preferred, if an outer housing of the coaxial socket connector is also one part with the base. The outer housing may further comprise a mechanical reference plane and/or centering means. It may also comprise locking means for a plug connector like a thread, preferably an outer thread, a protrusion or bayonet components.

In another preferred embodiment, the outer housing of the coaxial socket connector is screwed, soldered or welded to the base. It may have a thread fitting to a thread at the base and/or the spring loaded contact elements. The outer housing may further comprise a mechanical reference plane and/or centering means. It may also comprise locking means for a plug connector like a thread, a protrusion or bayonet components. This embodiment significantly simplifies manufacturing, as the spring loaded contact elements together with the base may be manufactured in one step while the outer housing may be manufactured separately. This would also allow using different materials for the spring loaded contact elements and for the outer housing.

In a further embodiment, to provide a high-quality low PIM electrical contact, means for positioning of the plug connector in relationship to the socket connector may be provided. The plug connector may have a mechanical contact surface at a right angle to its center axis. The socket connector may have a corresponding mechanical contact surface, which also is at a right angle to the connector's center axis. The mechanical contact surfaces define a mechanical reference plane for each connector. When mated, both mechanical contact surfaces preferably are in close contact with each other. Therefore, the mechanical contact surfaces define the spatial relationship of the plug connector and the socket connector in the direction of the center axis, when the connectors are mated. This may allow for a precise positioning of the plug connector relative to the socket connector. Preferably, the mechanical contact surfaces are not part of the outer conductors' electrical contacts, as known from prior art. Instead, the mechanical contact surfaces may be separate surfaces, distant from the spring loaded contact elements.

The coaxial connectors furthermore may have precision centering means for aligning the center axis of the plug connector with the center axis of the socket connector. The precision centering means preferably are distant from the spring

loaded contact elements. Preferably, the plug connector preferably has a cylindrical outer surface of the outer conductor, while the socket connector preferably has a cylindrical inner surface of the outer conductor. This may also be reversed, such that the plug connector preferably has a cylindrical inner surface of the outer conductor, while the socket connector preferably has a cylindrical outer surface of the outer conductor. Furthermore, the precision centering means may be distant from the mechanical contact surfaces defining the spatial relationship of the plug connector and the socket connector in the direction of the center axis. The cylindrical inner surface preferably fits tightly into the cylindrical outer surface and therefore limits parallel displacement of both center axes, so that the center axis of the plug connector is aligned with the center axis of the socket connector. Alternatively, the precision centering means may have a conical shape comprising a conical surface at the plug connector and at the socket connector. Furthermore, it is preferred, if the precision centering means and/or the mechanical contact surfaces are sized to prevent tilting of the plug connector against the socket connector.

Due to the precision positioning means the location of the plug connector with respect to the socket connector is laterally (radially) and axially within a comparatively low tolerance. When mated, the spring-loaded contact elements of the socket connector's outer conductor are in electrical contact with the outer conductor of the plug connector at a plug connector contact surface. Due to the high precision centering, the contact forces of all spring-loaded contact elements are equal. This results in an even current distribution and therefore high return loss and low passive intermodulation. Allowing for a simple and low pressure mating of the connectors, a conical section is provided at the plug connector's outer conductor, which continuously forces the spring-loaded contact elements to a smaller radius when mating the connector. Dependent on the slope of the conical section low insertion forces and high contact pressures may be obtained.

Herein the term of “one part” relates to a monolithic embodiment. Accordingly, the connector base, the outer conductor and optionally, the outer housing are made of one part. This means that they are machined in one piece, molded in one piece or manufactured otherwise in one piece such there are no interconnections between the connector base, the outer conductor and optionally, the outer housing.

Description of Drawings

In the following the invention will be described by way of example, without limitation of the general inventive concept, on examples of embodiment with reference to the drawings.

Figure 1 shows a coaxial socket connector and a coaxial plug connector according to the invention.

Figure 2 shows the coaxial socket connector and the coaxial plug connector in a sectional view.

Figure 3 shows the socket connector and the plug connector mated in a sectional view.

Figure 4 shows a detail of the mated connectors.

Figure 5 shows a further detail of the connectors.

Figure 6 shows a screw-in version of the connector.

Figure 7 shows a further screw-in version of the connector.

In figure 1, a coaxial socket connector 11 and a coaxial plug connector 10 are shown. The coaxial socket connector 11 comprises at least one center conductor 31 and one outer conductor 30. The outer conductor comprises a plurality of slits 35 with lands in between, forming a plurality of spring loaded contact elements 36 at its socket connector-facing end. A center axis 52 of the socket connector is defined by the center of center conductor 31.

The complementary coaxial plug connector 10 comprises at least one center conductor 21 and one outer conductor 20. A center axis 51 of the plug connector is defined by the center of center conductor 21. When mated with the coaxial socket connector 11, the center axis 51, 52 coincide.

Preferably, at least one locking means 29, 39 is provided for locking or fastening the plug connector 10 to the socket connector 11. The at least one locking means 29 of the plug connector 10 interfaces with the at least one locking means 39 of the socket connector 11. The locking means may be of screw type like a thread or bayonet type. The Plug connector may have a nut 27 or a handle for rotating the locking means 29 and therefore initiating a locking action.

Figure 2 shows sectional views of the socket connector 11 and the plug connector 10.

According to a first embodiment, the socket connector 11 has a connector base 37 for mounting the connector. The base may be mounted to any device like a metal plate, a housing or similar. Preferably, the base comprises a flange, most preferably a rectangular flange. The flange may be held by at least one screw which may pass through at least one hole 46. The base may also have a cylindrical shape, preferably having a thread, such that it may be held in a hole and locked by a nut. Preferably, the base serves as a ground contact.

The outer conductor 30 comprising a plurality of spring loaded contact elements 36 is one part with the base 37. Due to this monolithic embodiment, there is no electrical connection in the current path of the outer conductor between two parts of the outer conductor, which may have a thin oxide layer generating PIM. Therefore, PIM is further minimized. A benefit of this embodiment is, that there are no additional mechanical tolerances by fitting two parts like the outer conductor and the base, as the one part may be made in one manufacturing step. This leads to a higher precision and lower position tolerances, specifically of the mechanical contact surface and the precision centering means, which further leads to lower PIM.

In another preferred embodiment, the outer housing 38 of the coaxial socket connector is screwed, soldered or welded to the base 37. The outer housing 38 may have an outer housing thread 61 fitting to a base thread 62 at the base and/or at the spring loaded contact elements 30 (being one part with the base). Preferably, the outer housing 38 has an inner thread 61 adapted to fit to an outer thread 62 of the base 37. The outer housing 38 may further comprise a mechanical reference plane and/or centering means. It may also comprise locking means for a plug connector like a thread, a protrusion or bayonet components. This embodiment significantly simplifies manufacturing, as the spring loaded contact elements together with the base may be manufactured in one step while the outer housing may be manufactured separately. This would also allow using different materials for the spring loaded contact elements and for the outer housing. Also here a benefit is the increased mechanical precision further leading to reduced PIM. Due to the larger length of the outer housing compared to the base thickness, a thread 61, 62 as well as corresponding soldering or welding surfaces may have a larger length compared to the small base thickness into which the outer conductor may have been press-fitted previously. The larger length further results in higher mechanical precision.

Preferably, the outer conductor 20 of plug connector 10 fits around the outer conductor 30 of socket connector 11, therefore having a larger diameter then the outer conductor 30. In an alternate embodiment, outer conductor 20 of plug connector 10 may fit within the outer conductor 30 of socket connector 11, having a smaller diameter than the outer conductor. Furthermore, the center conductor 21 of the plug connector 10 and the center conductor 31 of the socket connector 11 may be connected together. Preferably, the socket connector's 11 center conductor 31 is a female connector while the plug connector's 10 center conductor 21 is a male connector. Alternatively, the gender may be reversed. The center conductors 21, 31 are held within the outer conductors 20, 30 by means of insulators 40, 45.

In a preferred embodiment, precision positioning of the plug connector 10 in relation to the socket connector 11 is achieved by the following means:

- The position along (in the direction of) the center axis 51 of the plug connector 10 and the center axis 52 of the socket connector 11 is defined by a mechanical contact surface 22 of the plug connector and a mechanical contact surface 32 of the socket connector, which are in close contact, when the connectors are mated. The contact plane defined by the mechanical contact surfaces is the mechanical reference plane of the connector.

- Precision centering, e.g. alignment of the center axis 51 of the plug connector 10 and the center axis 52 of the socket connector 11 is done by a plug connector's precision centering means 23 which fits into a socket connector's precision centering means 33.

The plug connector's precision centering means 23 preferably has a cylindrically shaped precision-machined outer contour. The plug connector's precision centering 23 means preferably is part of the outer conductor, which allows keeping

mechanical tolerances low, but it may also be separate from the outer conductor. Furthermore, the socket connector's precision centering means 33 preferably has a cylindrically shaped precision-machined inner contour, tightly fitting around the plug connector's precision centering means 23. This socket connector's precision centering 33 means may be part of the outer conductor 30, but may also be separate from the outer conductor 30. When mated, the precision centering means 23, 33 align the center axis 51 of the plug connector and the center axis 52 of the socket connector.

For achieving a good electrical contact, the socket connector's outer conductor 30 has a plurality of slits 35 extending from the plug connector-facing end of the outer conductor 30 and forming a plurality of spring loaded contact elements 36. When mated, these spring-loaded contact elements 36 of the outer conductor 30 electrically contact the plug connector at a contact surface 24.

Figure 3 shows both connectors 10, 11 mated together.

Figure 4 shows a base 37 with the socket connector outer conductor 30 but without further components.

Figure 5 shows a further embodiment. Here, the outer housing 38 of the coaxial socket connector 11 is also one part with the base 34. Therefore, the outer housing thread 61 and the base thread are no more required. This monolithic embodiment is a very simple and robust design.

The outer housing 38 may further comprise a mechanical reference plane and/or centering means. It may also comprise locking means 39 for a plug connector like a thread, a protrusion or bayonet components.

A benefit of this embodiment is, that there are no additional mechanical tolerances by fitting two parts like the outer conductor and the base, as the one part may be made in one manufacturing step. This leads to a higher precision and

lower position tolerances, specifically of the mechanical contact surface and the precision centering means, which further leads to lower PIM. As this embodiment base 34 includes the outer conductor 30 and the outer housing 38, this has the lowest total mechanical tolerances leading to the lowest PIM.

Figure 6 shows a screw-in version of the connector. This embodiment is very similar to the previous embodiments, but it has no flange. Instead, the base 71 comprises a bearing surface 76. The outer housing 77 comprises an outer thread 73 for holding a nut 74 which may be tightened to hold any device like a metal plate, a housing or similar between the bearing surface and the nut. There may be a sealing 75 close to the bearing surface.

Figure 7 shows a further screw-in version of the connector. Here, the base 72 also includes the outer housing 77.

List of reference numerals

10	coaxial plug connector
11	coaxial socket connector
20	plug connector outer conductor
21	plug connector center conductor
22	plug connector mechanical contact surface
23	plug connector precision centering means
24	plug connector outer conductor contact area
25	circular protrusion
28	O-ring
29	locking means
30	socket connector outer conductor
31	socket connector center conductor
32	socket connector mechanical contact surface
33	socket connector precision centering means
34	connector base with outer housing
35	slits
36	spring loaded contact elements
37	connector base
38	outer housing
39	locking means
40	insulator
45	insulator
46	screw hole
51	center axis of the plug connector
52	center axis of the socket connector
61	outer housing thread

62 base thread

71 connector base

72 connector base with outer housing

73 mounting thread

74 nut

75 sealing

76 bearing surface

77 outer housing

Claims

1. Coaxial connector (11) comprising at least

   - a center conductor (31) defining a center axis (52) of the connector,
   - an outer conductor (30) coaxial to the center conductor (31), the outer conductor (30) having a basically cylindrical shape with slits (35) forming a plurality of spring loaded contact elements (36),
   - a base (34, 37, 71, 72) for mounting the coaxial connector (11), the base (34, 37, 71, 72) being one part with the outer conductor (30),

   characterized in, that

   the base (34, 37, 71, 72) comprises an outer thread (62), and
   an outer housing (38, 77) is provided, further comprising an inner thread (61), the inner thread (61) matches to the outer thread (62).

2. Coaxial connector (11) according to claim 1,
   characterized in, that
   the coaxial connector (11) is a socket connector.

3. Coaxial connector (11) according to claim 1 or 2,
   characterized in, that
   an outer housing (38, 77) is provided at the base (34, 37, 71, 72) forming one part with the base.

4. Coaxial connector (11) according to claim 1 or 2,
   characterized in, that
   an outer housing (38, 77) is screwed, welded or soldered to the base (34, 37).

5. Coaxial connector (11) according to any one of claims 1 to 4, characterized in, that the base (34, 37) comprises a flange.

6. Coaxial connector (11) according to any one of claims 3 to 4, characterized in, that the base (71, 72) comprises a bearing surface (76) and the outer housing (38, 77) comprises an outer thread (73).

7. Coaxial connector (11) according to any one of the preceding claims, characterized in, that a mechanical contact surface (32) at a right angle to the center axis and distant from the spring loaded contact elements (36) to define the spatial relationship of the coaxial connector and a plug connector (10) in the direction of the center axis, when the connectors are mated, is provided, and at least one precision centering means (33) is provided for aligning the center axis (51) of the connector to a center axis (52) of the socket connector (10).

8. Coaxial connector (11) according to claim 7, characterized in, that the at least one precision centering means (33) has a cylindrical outer contour which is precision machined and matches to the at least one precision centering means of a coaxial plug connector (10).

9. Coaxial socket connector (11) according to claim 7 or 8, characterized in, that

the at least one precision centering means (33) has a cylindrical inner contour which is precision machined and matches to the at least one precision centering means of a coaxial plug connector.

10. Coaxial plug connector (10) comprising at least

- a center conductor (21) defining a center axis (51) of the connector,
- an outer conductor (20) coaxial to the center conductor, the outer conductor having a basically cylindrical shape with a contact area (24),
- a mechanical contact surface (22) at a right angle to the center axis and distant from the contact area (24) to define the spatial relationship of the plug connector and a socket connector in the direction of the center axis, when the connectors are mated,

characterized in, that

at least one precision centering means (23) is provided for aligning the center axis (51) of the connector to a center axis (52) of a mating socket connector (11).

11. Coaxial plug connector (10) according to claim 11,

characterized in, that

a circular protrusion (25) is provided close to the contact area (24) which has the same inner diameter as spring loaded contact elements (36) of a coaxial socket connector.

12. Coaxial connector (10, 11) according to any one of the preceding claims,

characterized in, that

an O-ring (28) is provided for sealing a gap between the plug connector outer conductor (20) and the socket connector outer conductor (30) when mated.

13. Coaxial connector system comprising of a coaxial connector (11) according to claim 1 and a coaxial plug connector (10) according to claim 11.

Fig. 1

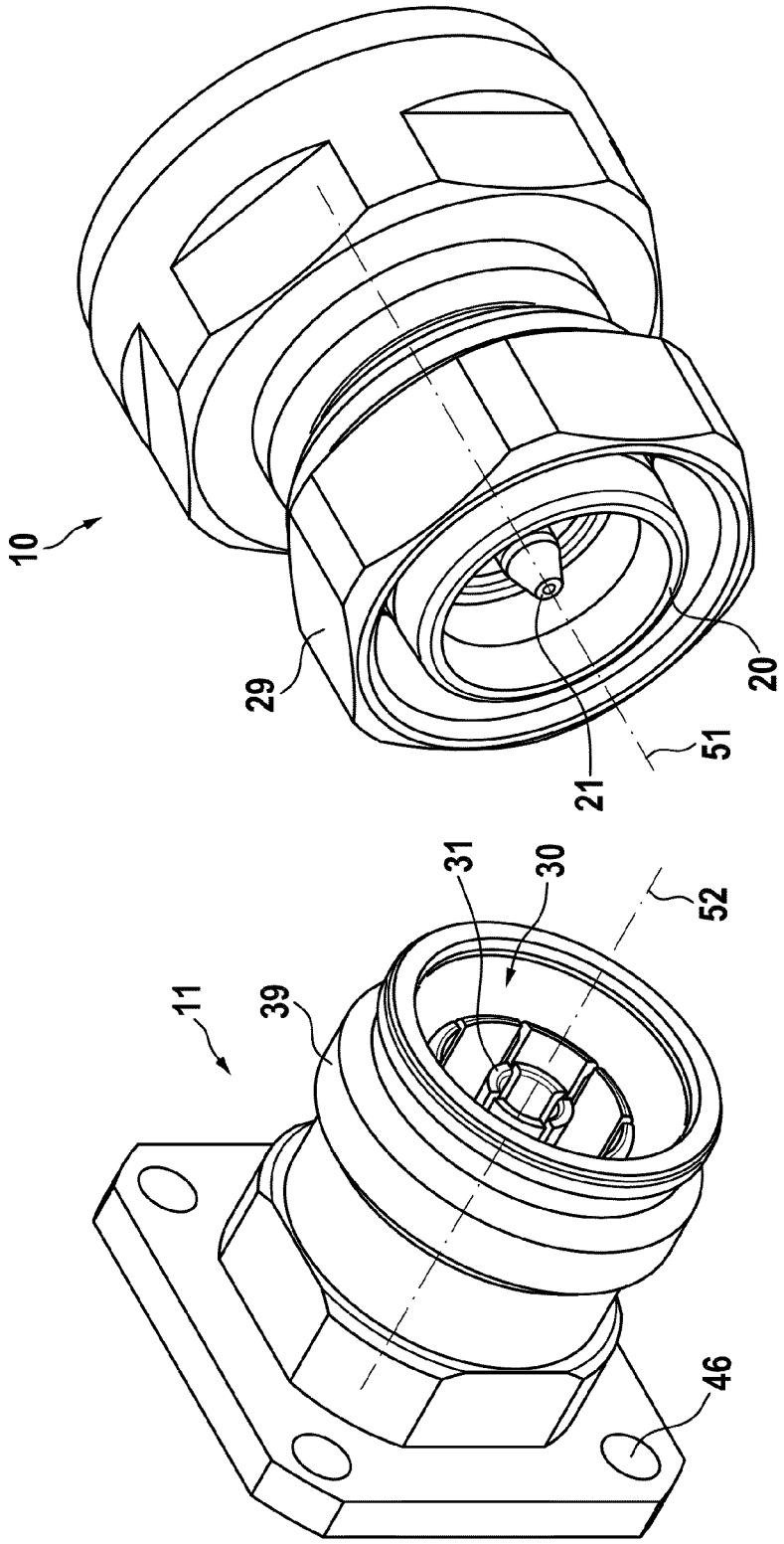

Fig. 2

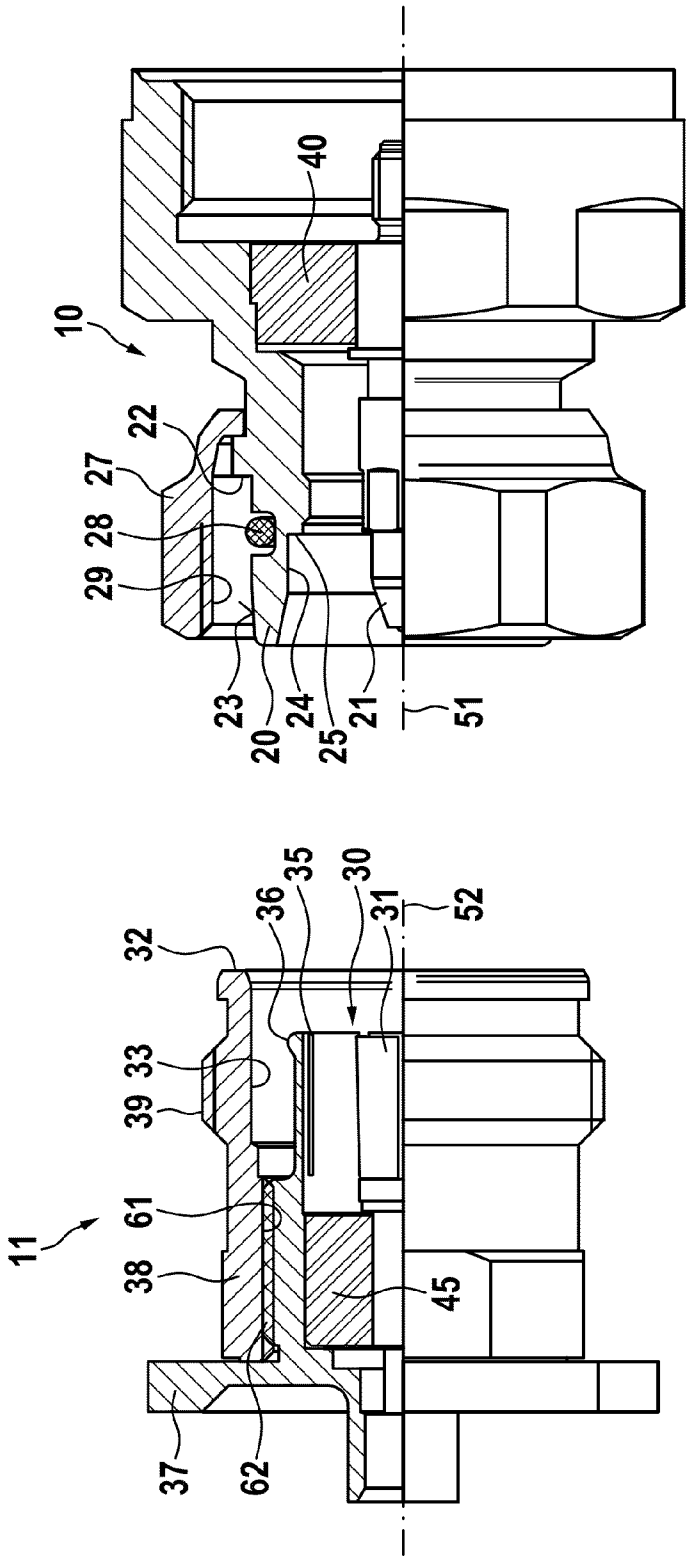
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Fig. 3

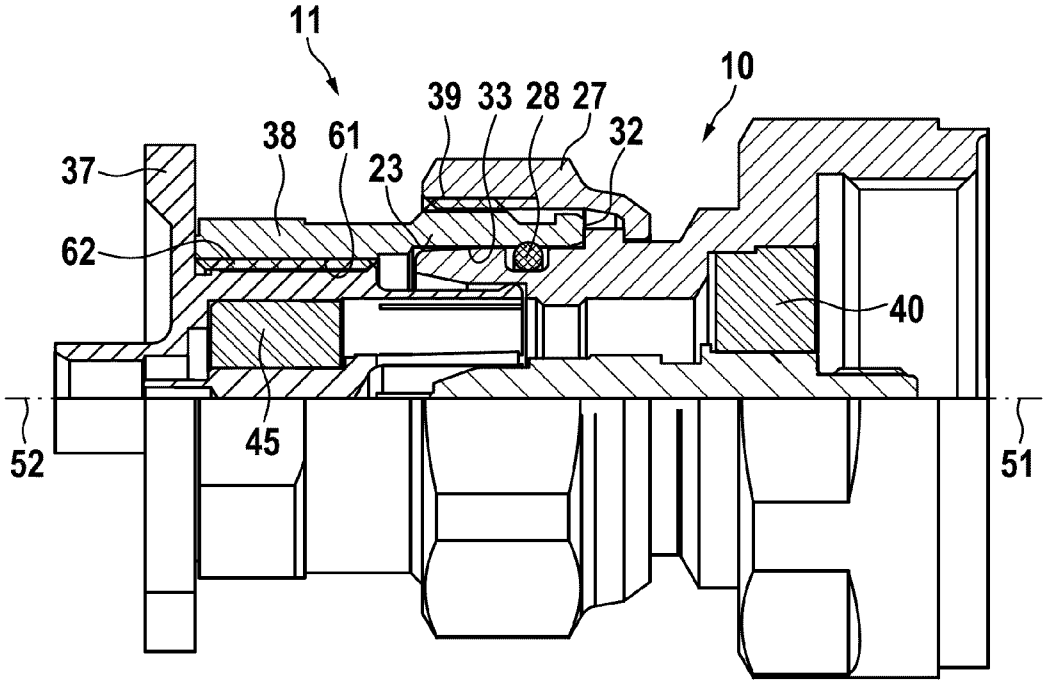

Fig. 4

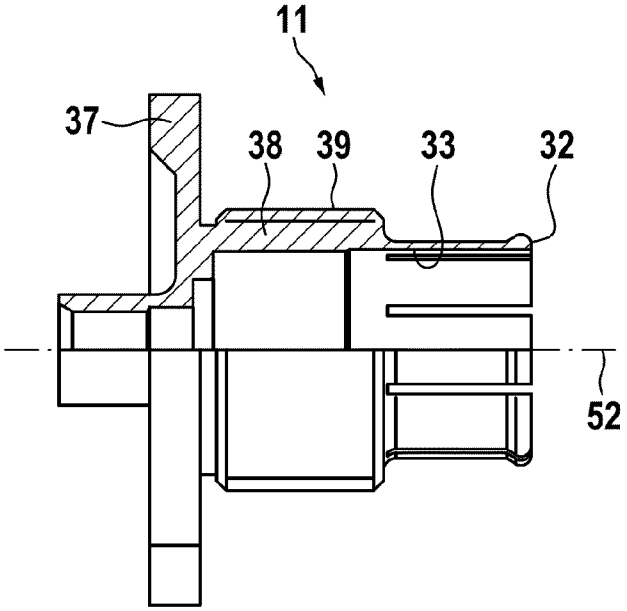

Fig. 5

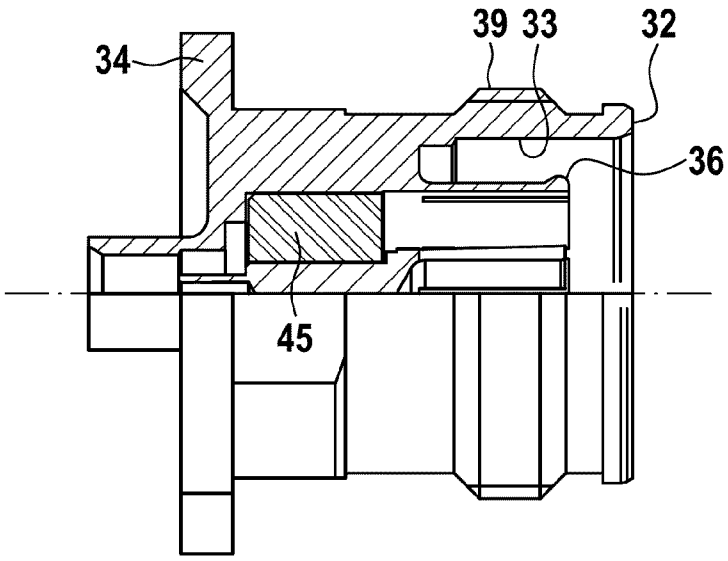

Fig. 6

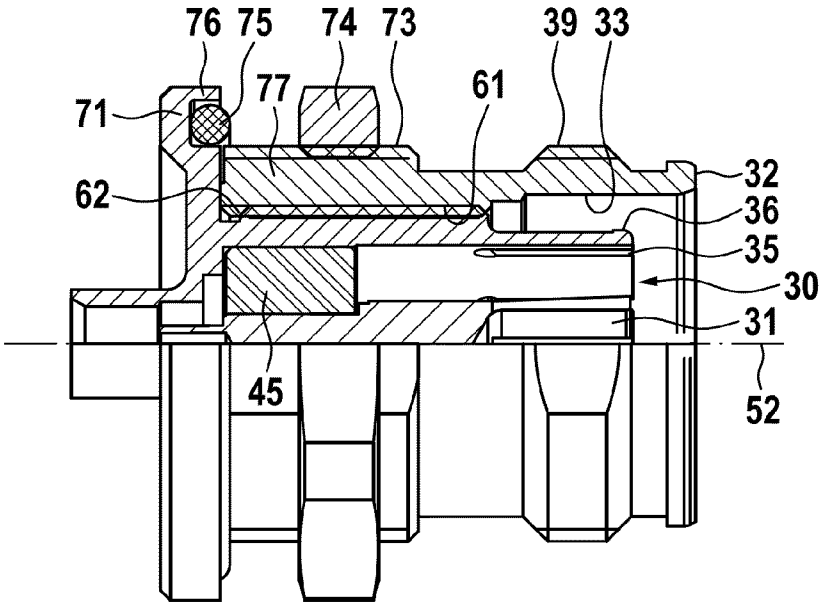
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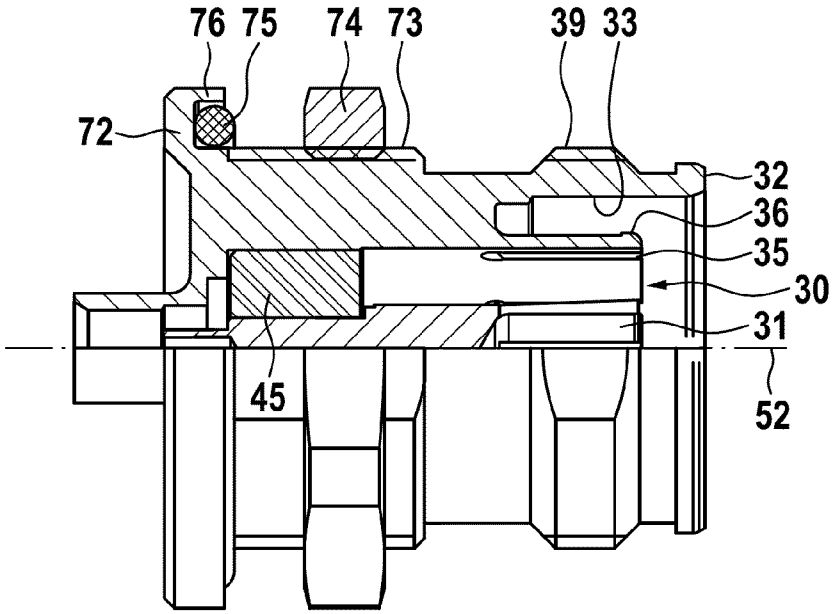
Fig. 7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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/069641

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01R24/44 H01R24/52
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2015/192382 A1 (SHENZHEN TATFOOK TECHNOLOGY CO [CN]) 23 December 2015 (2015-12-23) abstract; figures 4-6	1-9,13
Y	JP 2010 257678 A (HITACHI INT ELECTRIC INC) 11 November 2010 (2010-11-11) abstract; figures 5-8	1-9,13
Y	DE 18 13 161 U (SPINNER GEORG DIPL ING [DE]) 15 June 1960 (1960-06-15) figure 1	7-9
A	CA 2 432 051 A1 (CHEN PARRY [TW]) 16 November 2004 (2004-11-16) page 6 - page 7; figures 3,4	1,2,6

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
5 October 2017	18/12/2017

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/069641

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 84 24 348 U1 (SIEMENS) 15 November 1984 (1984-11-15) figure 1	1,2,6
A	US 2009/280682 A1 (ZHANG XIAO-GUO [CN] ET AL) 12 November 2009 (2009-11-12) paragraph [0017]; figures 1,2	3

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Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-9(completely); 13(partially)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9(completely); 13(partially)

   A coaxial connector comprising a center conductor, an outer conductor and a base wherein the base is one part with the outer conductor, the base comprises an outer thread, and an outer housing is provided, further comprising an inner thread, the inner thread matches to the outer thread .

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2. claims: 10-12(completely); 13(partially)

   A coaxial plug connector comprising a center conductor, an outer conductor and a mechanical contact surface wherein at least on precision centering means is provided for aligning said connector with a mating socket connector.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/069641

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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