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(71) Applicant: **Airbus Defence and Space Limited**
**Stevenage**
**Hertfordshire SG1 2AS (GB)**

(72) Inventor: **LILLER, Simon**
**Portsmouth, PO3 5PU (GB)**

(74) Representative: **Walaski, Jan Filip**
**Venner Shipley LLP**
**200 Aldersgate**
**London EC1A 4HD (GB)**

(54) **MULTI-WAY RADIO FREQUENCY INTERFACE AND CONNECTOR**

(57) A new system for connecting multiple RF connectors in RF systems, particularly for use in satellite payloads, is proposed. The described system reduces assembly time and improves reliability, by combining a plurality of RF connections within a housing of a connector which is fastened to a corresponding housing of a further connector. Also provided is an interface device, for adding functionality to the connections described.

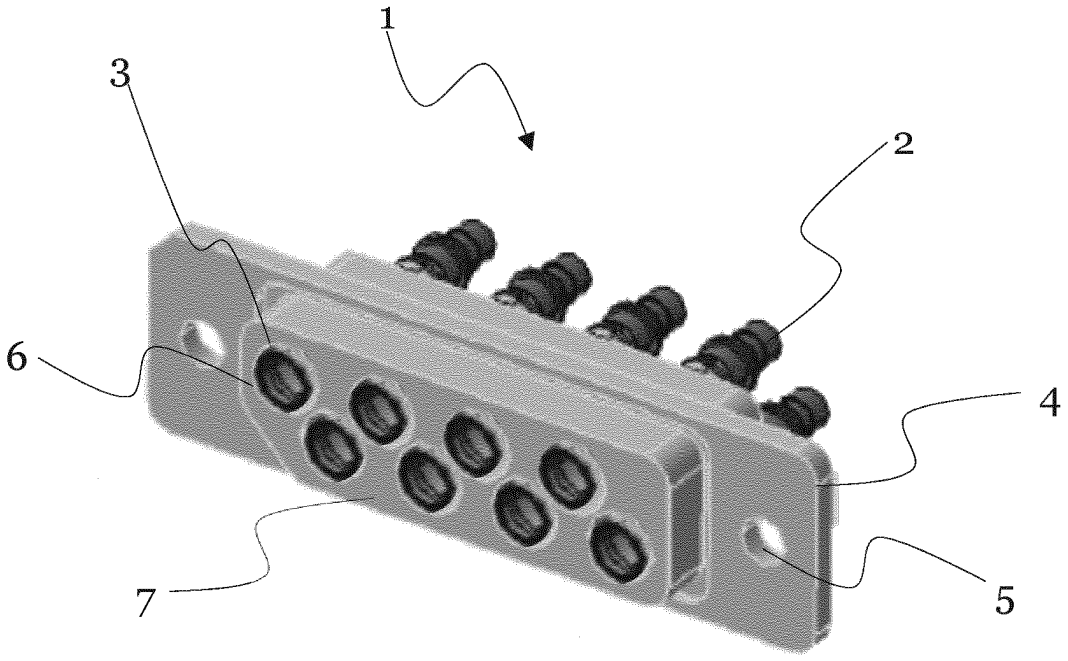


Figure 1

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## Description

### Field of the Invention

**[0001]** The present invention relates to multi-way radio frequency connectors and multi-way radio frequency interface devices.

### Technical Background

**[0002]** Telecommunication systems comprise, in part, complex signal networks capable of carrying and operating upon a variety of input signals. When constructing such a system for use in a variety of military or commercial technologies, for example, a satellite payload, it is necessary to make numerous radio frequency (RF) connections, to build up the signal network.

**[0003]** A popular conventional technique used to implement such connections is to employ threaded RF connectors, which are known to have good RF signal performance. Examples of typical connectors are sub-miniature connectors (e.g. threaded types A or K, known as SMA or SMK connectors) or Threaded Neill-Concelman (TNC) connectors. Each connector of this type must be positioned and tightened independently, and subsequently inspected, to ensure that the RF signal can propagates correctly through the connector. Such a process is time consuming, particularly as the size of the network increases, and can lead to variable coupling between connections due to the fact that each connection is independently secured.

**[0004]** An alternative RF connection technique, which aims to address such complexities, is to use push-fit connectors, such as sub-miniature type P (SMP) connectors. These connectors do not require the application of a torque to tighten the connection, and are hence capable of faster individual assembly. However, such connectors do not provide robust and repeatable RF contacts, especially in the presence of the vibrations and thermal variation which payloads must typically endure, for example in take-off, and during operation, as a satellite payload. As such, such connectors are typically used only for test applications.

**[0005]** Embodiments of the present invention aim to provide an improved connector, which combines advantages of good RF signal performance with ease of assembly.

### Summary of Invention

**[0006]** According to an aspect of the present invention, there is provided a multi-way radio frequency, RF, connector comprising a housing comprising a plurality of recesses for receiving each of a respective plurality of RF conductors to connect to a further plurality of RF conductors, a plurality of retention means, each accommodated within a respective one of the plurality of recesses, wherein each retention means is configured to retain the position of a respective one of the plurality of RF conductors with respect to the recess, a fastening means for fastening the housing to the housing of a further connector to secure the connection of each RF conductor to a respective one of the further plurality of RF conductors when retained by the further connector.

**[0007]** The housing may further comprise a guiding portion surrounding the plurality of recesses, to guide the connection of the plurality of RF conductors with respect to the further plurality of further RF conductors.

**[0008]** The guiding portion may comprise a plug to interface with a socket of the further connector.

**[0009]** The guiding portion may comprise a socket to interface with a plug of the further connector.

**[0010]** The fastening means comprise a torque indication for indicating that the connector is fastened, via application of a predetermined torque to the fastening means, to the further connector with a predetermined tightness.

**[0011]** According to another aspect of the present invention, there is provided a radio-frequency, RF, cable harness comprising the above connector and a plurality of RF cables, wherein the plurality of RF cables are the plurality of RF conductors.

**[0012]** The plurality of RF cables may comprise a respective plurality of sub-miniature type P, SMP, RF contacts for connecting to the further plurality of RF conductors.

**[0013]** According to another aspect of the present invention, there is provided a system comprising the above connector and the further connector, wherein the further connector is secured to the connector by a respective fastening means.

**[0014]** According to another aspect of the present invention, there is provided a system comprising the above connector and a plurality of the further connectors, wherein each of the further connectors is secured to the connector by a respective fastening means, wherein the recesses of the connector are divided into groups each arranged to receive a group of RF conductors for connecting to respective plurality of RF conductors retained by a respective one of the plurality of further connectors.

**[0015]** According to another aspect of the present invention, there is provided an interface device configured to be coupled between a first and a second multi-way radio frequency, RF, connector, comprising an interface housing comprising a plurality of interface components, wherein each interface component comprises a first portion configured to connect to a respective first RF conductor when retained by the first connector, and a second portion configured to connect to a respective second RF conductor when retained by the second connector, wherein the plurality of interface components are arranged to perform one or more functions on RF signals received from the first and/or second connectors, and an interface fastening means for fastening the interface housing to the first and second connectors to secure the connection of each interface component.

**[0016]** The one or more functions may comprise at least one of attenuation, RF loading, and signal passing.

**[0017]** The interface housing may comprise a first guiding portion surrounding the first portions of the interface components and a second guiding portion surrounding the second portions of the interface components, the first and second guiding portions configured to guide the coupling of the interface device to the first and second connectors respectively.

**[0018]** The first and second portions of the interface components may comprise a plurality of sub-miniature push-on, SMP, RF contacts.

**[0019]** The systems above may further comprise the above interface device, wherein the connector is the first connector and the further connector is, or the plurality of further connectors are, the second connector.

**[0020]** The systems above may further comprise a plurality of the interface devices, wherein each of the plurality of interface devices is arranged to couple the first connector to a respective one of the plurality of second connectors.

**[0021]** Embodiments of the present invention are capable of making multiple, robust connections simultaneously whilst ensuring that each individual connection within the connector is appropriately mated and fastened with minimal variability between connections.

## Brief Description of Drawings

**[0022]**

Figure 1 shows a male multi-way RF connector, according to embodiments of the present invention;

Figure 2 shows a female multi-way RF connector, according to embodiments of the present invention;

Figures 3a and 3b show two perspective views of a multi-way RF harness, according to embodiments of the present invention;

Figures 4a and 4b show two perspective views of a system comprised of two coupled multi-way RF connectors, according to embodiments of the present invention;

Figure 5a and 5b show two perspectives of a system of three multi-way RF connectors with a first and second connector both being coupled to a third connector, according to embodiments of the present invention;

Figure 6 shows a multi-way RF interface device, according to embodiments of the present invention;

Figure 7 shows a system comprised of an interface device coupled to two multi-way RF cable harnesses, according to embodiments of the present invention.

## Detailed Description

**[0023]** Figure 1 shows a perspective view of a multi-way RF connector 1, according to embodiments of the present invention. The connector 1 of Figure 1 is capable of facilitating eight RF connections. Each RF connection may between a pair of RF signal conductors such as a cables and/or a structure on a panel or circuit board.

**[0024]** The connector 1 is arranged to receive an RF conductor via a respective recess 6 in housing 4. Each recess 6 comprises a retention means 3, such a cir-clip, which retains both the lateral position and longitudinal position, relative to a direction of insertion of the RF cable or RF signal-carrying structure, relative to the housing 4. Figure 1 shows an example embodiment in which end portions 2 of RF cables are inserted into and retained within recesses 6 of the housing 4.

**[0025]** The RF conductor received by the connector 1 comprises a coupling means to achieve connection of the contact of the conductor to that of a further RF conductor. In some embodiments, the connector 1 is arranged to accommodate a sub-miniature push-on, SMP, RF coupling means. Each recess 6 is arranged to accommodate at least a portion of each respective coupling means.

**[0026]** A first connector 1 is arranged to couple to a second connector via the fastening means 5 of the housing 4. As will be described further below, such a second connector is arranged to retain the position of a respective set of RF conductors to be connected to the RF conductors which are retained by the first connector. The connection is via a combination of electrical contacts, secured by mechanical coupling means, to be described below. The RF conductors retained by each of the first and second connectors couple via a mechanism such as SMP connection, as described above, although it will be appreciated that any appropriate push-fit connection mechanism may be used. In alternative embodiments, threaded coupling nuts may be removed from RF cables to enable a push-fit connection between the pin of a coaxial cable and a corresponding socket of a further cable.

**[0027]** The fastening means 5 enables a relaxation of the mechanical coupling requirement imposed on the coupling means of each RF connection, such that mechanically sprung fingers of an SMP contact, for example, are sufficient to achieve and maintain the required RF signal connection. The housing 4 can be considered as performing mechanical alignment and the majority of the mechanical work needed to secure the RF connection robustly. The fastening means 5 is configured to ensure that the coupling of the contacts of the RF conductors 1 to the contacts of RF conductors retained by the further connector is robust and uniform. Such coupling is resistant to disturbance through temperature and vibration.

**[0028]** As above, each RF conductor is to be accommodated within a respective one of a plurality of recesses 6, formed within the housing 4. In the presently illustrated embodiments, the eight recesses 6 are arranged within the housing 4 as an array having two rows of four recesses, the rows offset from each other to optimise use of space such that each recess 6 is diagonally positioned with respect to its nearest neighbour.

**[0029]** By retaining multiple RF conductors via a single connector housing 4, the present embodiments thus enable fast and reliable assembly of multiple RF connections simultaneously, particularly where SMP connections are employed, whilst further allowing the connections to withstand the effects of external forces.

**[0030]** The embodiments contrast with conventional use of individual screw-fit or SMP connections. In such conventional configurations, each RF connection would need to be fastened, tightened with appropriate torque in the case of threaded connections, and inspected individually. Doing so would be considerably more time consuming. For a typical RF signal network of a satellite payload, the time taken to secure and inspect all connections may be reduced from 45 hours to 45 minutes by adopting the multi-way connector 1 of embodiments of the present invention, rather than using individual connections. Furthermore, where each individual connection is to be secured separately, in conventional techniques, there may be a variability in the coupling between each RF connection, exacerbated in the presence of thermal fluctuation and vibration present in typical satellite payload applications.

**[0031]** Although Figure 1 shows the fastening means 5 as a pair of recesses, capable of receiving a bolt to be fastened with a nut, it will be appreciated that the connector 1 of Figure 1 may comprise any suitable fastening means. In some embodiments, the fastening means 5 maybe a screw, a quarter-turn fastening, a jackpost mount or any other appropriate fastening means capable of suitably torquing the connection. In some embodiments, the fastening means 5 comprise a torque indication for indicating that the connector 1 is fastened, via application of a predetermined torque to the fastening means 5, to a further connector with a predetermined tightness. For example, such a torque indication may comprise a line indicating the level to which a screw must be fastened to ensure that the coupling of the RF conductors to those retained by a further connector meets the specified requirements of robustness and uniformity. The implementation of such a torque indication reduces the length of time spent inspecting the fastenings and further improves the efficiency of assembly.

**[0032]** In some embodiments, the housing 4 comprises a guiding portion 7 surrounding the plurality of recesses 6, configured to guide the coupling means of each RF conductor to the respective coupling means of a corresponding RF conductor retained by a further connector. In the embodiments of Figure 1, the guiding portion 7 is configured to be a plug, capable of interfacing with a socket of a further connector. The nature of the guiding portion of the housing 4 is, in such embodiments, such that the connector 1 can be considered as a 'male' connector. Such an arrangement ensures that the coupling means of the RF conductors to be connected are appropriately aligned.

**[0033]** Figure 2 shows a perspective view of a multi-way RF connector 11, according to embodiments of the present invention. The connector 11 of Figure 2 is substantially similar to the connector 1 of Figure 1, comprising a housing 14; a plurality of recesses 16, formed within the housing 14; a plurality of retention means 13 for retaining the position of a respective plurality of RF conductors configured to interface with a corresponding plurality of RF conductors of a further connector; and a fastening means 15 for fastening the housing 14 to the housing of the further connector to secure the coupling of each RF conductor contact. Each of these elements may be arranged in a manner substantially similar to the embodiment of Figure 1. End-portions 12 of RF conductors are also illustrated.

**[0034]** However, the embodiment of Figure 2 shows a guiding portion 17, surrounding the plurality of recesses 16, configured as a socket or shell, arranged to interface with a plug of a further connector. Such a further connector may comprise, for example, the connector 1 of Figure 1. The nature of the guiding portion 17 of the housing 14 is, in the embodiments represented by Figure 2, such that the connector 11 can be considered as a 'female' connector. Such an arrangement ensures that the coupling means of the RF conductors to be connected are appropriately aligned.

**[0035]** Although Figures 1 and 2 each show eight-way connectors, it will be appreciated that the multi-way connectors, according to embodiments of the present invention, are capable of simultaneously coupling *N* RF conductors, where N is any number greater than one. In each case, some or all of each of the N connections may be unidirectional or bidirectional.

**[0036]** Figures 3a and 3b show perspective views of the front and rear of an RF cable harness 21, 22 respectively, according to embodiments of the present invention. The harness 21, 22 comprises a multi-way RF connector, such as that described with reference to Figure 1 or Figure 2, and a respective plurality of RF cables 23, 24,

**[0037]** A first and second RF cable harness each according to embodiments of the present invention, for example those shown in Figures 3a and 3b, maybe connected to one another through the mating of the respective RF connectors. Such a connection enables propagation of a signal from the RF cables 23 of the first RF harness 21 through to the RF cables 24 of the second RF harness 22. Such propagation may be in a single direction or bi-directional. The cables 23, 24 of the RF harness 21, 22 maybe arranged such that all connections are single direction, bi-directional or a combination thereof.

**[0038]** As with Figures 1 and 2, Figures 3a and 3b show each show eight-way harnesses 21, 22, with an eight-way connector coupled to eight RF cables 23, 24. It will be appreciated that the harnesses 21, 22 of Figures 3a and 3b may alternatively be arranged to be N-way harnesses, according embodiments of the present invention, where N is any number greater than one. An N-way connector may be coupled to *N* RF cables. Further, it will

be appreciated that a Q-way harness may be achieved through coupling a P-way connector to Q RF cables, where $P > Q$. For example, a seven-way harness may be achieved for a particular application by coupling only seven RF cables to an eight-way connector, wherein the remaining RF contact of the eight-way connector effectively forms a null coupling. In some embodiments, it is possible to attenuate such a null coupling, as described in more detail below.

**[0039]** The relative ease by which each individual RF conductor can be connected enables reconfigurability of portions of the signal network in a way which does not affect connections which do not require removal. For example, it maybe possible to add or remove RF cables from connection to an eight-way connector with relative ease, based on SMP technology, for example, but the fastening of the eight-way connector ensures that there is no overall change in the way in which the connector is secured to a further connector.

**[0040]** Figures 4a and 4b show alternative perspectives of an exploded view of a system of two multi-way RF connectors 31, 32 fastened by respective fastening means 33 such that a connection is made between the contacts of the RF conductors of the first connector and the contacts of the RF conductors of the second connector. In some embodiments, each of the first and second connectors 31, 32 may be substantially similar to those described in relation to Figures 1 and 2. In such embodiments a guiding portion 36 of the first connector corresponds to a plug and a guiding portion 37 of the second connector corresponds to a socket such that the plug and socket are reciprocally coupled to one another.

**[0041]** The connectors 31, 32 of Figures 4a and 4b are coupled to one another using a fastening means 33. The fastening means may be substantially similar to that described with reference to Figures 1 and 2. When the fastening means 33 is secured it ensures that the contacts of the RF conductors of the first and second connectors 31, 32 are reciprocally coupled, as described in relation to Figures 1 and 2.

**[0042]** The representation of Figures 4a and 4b enables the securing of the two connectors 31, 32 to be shown in detail, although the specific nature of the connection maybe varied while remaining within the scope of the claims. In the illustrated embodiments, the fastening means 33 of the first and second connectors 31, 32 includes washers 38 either side of a mounting plate, and rubber gaskets 39. The use of washers 38 and the mounting plate ensures that the load applied by the fastening means 33 is equally distributed around the housing via the mounting plate, whilst rubber gaskets 39 ensure a level of electromagnetic compatibility (EMC).

**[0043]** Figures 5a and 5b show two perspective views of a system, according to embodiments of the present invention, of three multi-way RF connectors 41, 42, 43 each fastened by a respective fastening means 44, 45, 46 such that the contacts of the RF conductors of a first and second connector are coupled to the contacts of the RF conductors of a third connector. Each of the first, second and third connectors 41, 42, 43 may have a structure substantially similar to the connectors of Figure 1 and/or Figure 2. That is to say that each of the first, second and third connectors 41, 42, 43 comprise a housing 51, 52, 53; a plurality of recesses 54, 55, 56, formed within the housing 51, 52, 53; a plurality of retention means 47, 48, configured to retain both the lateral position and longitudinal position of an RF conductor, relative to a direction of insertion of an RF conductor ; and a fastening means 44, 45, 46 for fastening the housing of the first 51 and second 52 connector to the housing of the third 53 connector. It is noted that in the embodiments of Figures 5a and 5b, the RF conductors are shown as the ends of cables 57, 58, 59

**[0044]** The retention means 48, and the associated recesses, of the third connector are divided into a first group 49 and a second group 50, wherein the contacts of the RF conductors retained in the recess of the first group 49 are arranged to couple to the contacts of the RF conductors retained in the recess of the first connector 47 and the contacts of the RF conductor retained in the recess of the second group 50 are arranged to couple to the contacts of the RF conductor retained in the recess of the second connector (shown in a coupled state in Figures 5a and 5b).

**[0045]** The housing of the third connector 43 is arranged to be fastened to the respective housings of the first 51 and second 52 connectors via a fastening means 44, 45, 46. To this end, the first and second connectors 41, 42 of Figures 5a and 5b are each individually secured to the third connector 43 by their respective fastening means 44, 45, 46. That is to say that the first connector 41 may be mated with and fastened to the third connector 43 independently of the second connector 42. Similarly, the second connector 42 maybe mated with and fastened to the third connector 43 independently of the first connector 41. As such, at any point in time it is possible to have only the first 41, only the second 42, neither, or both of the first and second connectors 41, 42 coupled to the third connector 43.

**[0046]** The fastening means 44, 45, 46 may be substantially similar to that described with reference to Figures 1, 2, 4a and 4b. When the fastening means 44, 45, 46 are secured, RF connections between the first connector and third connector, along with the RF connections between the second connector and third connector, are ensured.

**[0047]** In some embodiments, the housing of the third connector 43 includes a guiding portion 60, surrounding the plurality of recesses 56 of the first and second groups 49, 50. The guiding portion 60 is configured to guide to guide the coupling means of each RF conductor of the first group 49 with the respective coupling means of each RF conductor of the first connector 41 and each respective coupling means of each RF conductor of the second group 50 with the respective coupling means of each RF conductor of the second connector 42. Similarly, the first

connector 41 also comprises a guiding portion 61 wherein the guiding portion 61 of the first connector 41 surrounds its respective plurality of recesses 54, and is arranged to guide the coupling of each respective coupling means of each RF conductor of the first connector 41 with the respective coupling means of each RF conductor48 of the first group 49 of the third connector 43. Further, the second connector 42 also comprises a guiding portion wherein the guiding portion of the second connector 42 surrounds its respective plurality of recesses 55, and is arranged to guide the coupling of each respective coupling means of each RF conductor of the second connector 42 with the respective coupling means of each RF conductor of the second group 50 of the third connector 43.

**[0048]** In some embodiments, such as that of Figures 5a and 5b, the guiding portion 60 of the third connector 43 comprises a socket divided into a first and second portion, housing the first and second groups 49, 50 of recesses 56 and receiving associated coupling means of each RF conductor respectively. In such embodiments, the guiding portion 61 of the first connector 41 and the guiding portion of the second connector 42 each comprise a plug configured to interface with the first and second portions of the plug of the third connector 43 respectively.

**[0049]** In other embodiments, the guiding portion 60 of the third connector 43 comprises a plug divided into a first and second portion, housing the first and second groups 49, 50 of recesses 56 and receiving associated coupling means of each RF conductor respectively. In such embodiments, the guiding portion 61 of the first connector 41 and the guiding portion of the second connector 42 each comprise a socket configured to interface with the first and second portions of the plug 60 of the third connector 43 respectively.

**[0050]** In further embodiments, the first portion of the guiding portion of the third connector comprises a plug, and the second portion of the guiding portion of the third connector comprises a socket. In such embodiments, the guiding portion of the first connector 61 comprises a socket configured to interface with the plug of the first portion of the third connector and the second connector comprises a plug configured to interface with the socket of the second portion of the third connector.

**[0051]** In another embodiment, the first portion of the guiding portion 60 of the third connector 43 comprises a socket, and the second portion of the guiding portion 60 of the third connector 43 comprises a plug. In such an embodiment, the guiding portion 61 of the first connector 41 comprises a plug configured to interface with the socket of the first portion of the guiding portion 60 of the third connector 43 and the second connector 42 comprises a socket configured to interface with the plug of the second portion of the guiding portion 60 of the third connector 43.

**[0052]** Although Figures 5a and 5b show two two-way connectors coupling to a single four-way connector, this is merely one embodiment. It will be appreciated any combination of *X Y*-way connectors may be connected to a single *Z*-way connector, where $Z=^{*}{}^{*}Y$, $X>1$ and $Y>1$. In such an arrangement, the Z contacts, and associated recesses, of the Z-way connector are split into P groups of Q, where $P=X$ and $Q=Y$.

**[0053]** As an example, a fourth connector may comprise an eight-way connector, divided into three groups of connections and associated recesses: a first group of two, a second group of two and a third group of four. Such an eight-way connector may be configured to interface with a first, second and third connector. In this example, the first connector comprises a two-way connector configured to interface with the first group of the fourth connector. Similarly, the second connector comprises a two-way connector configured to interface with the second group of the fourth connector. Finally, the third connector comprises a four-way connector, configured to interface with the third group of the fourth connector.

**[0054]** As such, it is not necessary for each connector to receive a common number of RF conductors. For example, a three-way connector and a five-way connector may each connect to a single eight-way connector.

**[0055]** Figure 6 shows a perspective view of an interface device 70, according to embodiments of the present invention, configured to be coupled between a first and second multi-way RF connector in order to perform one or more functions on RF signals received from the first and/or second connectors. The interface device comprises an interface housing 71, surrounding a plurality of interface components 72 mounted and retained within a corresponding plurality of recesses (not shown), and an interface fastening means 73. The first and second multi-way connectors could be any combination of the connectors described in relation to Figures 1 and 2.

**[0056]** Each interface component 72 comprises a first portion 74 and second portion (not shown), configured to interface with the contacts of each RF conductor of the first and second RF connectors respectively. The interface components 72 are each arranged to perform a function on the one or more RF signals received from each of the connectors. The functions performed by the interface components 72 may be homogeneous between maybe heterogeneous between components. In some embodiments, the one or more functions comprise at least one of attenuation, DC blocking, RF loading, and signal passing, and such functions are achieved in a 'passive' manner, without requiring and external power supply or control means to apply functions 'actively'. In some embodiments the first 74 and second portions of the interface components 72 comprise a plurality of sub-miniature push-on, SMP, RF contacts.

**[0057]** The fastening means 73 of Figure 6 is configured for fastening the interface housing 71 to the respective housings of the first and second connectors. The fastening means 73 may be substantially similar to that described with reference to Figures 1 and 2. Such fastening ensures the coupling of the first 74 and second

portion of the interface components 72 with the respective contacts of each RF conductor of the first and second connectors. The fastening means 73 is configured to ensure that the coupling of the interface components 72 of the interface device to the contacts of each RF conductor of the first and second connectors is robust and uniform. Such coupling is resistant to disturbance through temperature and vibration.

**[0058]** In some embodiments, the interface housing 71 comprises a first guiding portion 75 surrounding the first portions 74 of the interface components 72 and a second guiding portion 76 surrounding the second portions of the interface components 72, the first and second guiding portions 75, 76 are configured to guide the coupling of the interface device 70 to the first and second connectors respectively. The first and second guiding portions 75, 76 of the interface device may be configured to be the same as each other, or different.

**[0059]** In some embodiments, the first and second guiding portion 75, 76 are both plugs, configured to interface with respective sockets of the first and second connectors. In other embodiments, both the first and second guiding portion 75, 76 are sockets, configured to interface with respective plugs of the first and second connectors. In further embodiments, one of the first or second guiding portion 75, 76 is arranged to be a plug, configured to interface with a respective socket of the first or second connector; while the other one of the first or second guiding portion 75, 76 is arranged to be a socket, configured to interface with a respective plug of the first or second connector.

**[0060]** Figure 7 shows an exploded view of a system 80 achieved by combining embodiments of the present invention, comprising an interface device 81 fastened to first and second cable harnesses 82, 83 by respective fastening means 84, 85, 86, such that the first 87 and second (not shown) portions of the interface components 88 are coupled to the contacts of each RF conductor of the first 89 and second (not shown) connectors respectively. The interface device 81 is substantially similar to the interface device described with reference to Figure 6, whilst the first and second cable harnesses 82, 83 may be substantially similar to any combination of cable harnesses connectors described with reference to Figures 3a and 3b.

**[0061]** Although the interface device 81 has been described with reference to connection to a first and second RF harness 82, 83, it will be appreciated that such an interface device 81 may also be configured to interface with two or more connectors. For example, one or more interface devices 81 may be arranged to interface between the connectors illustrated in Figures 5a and 5b, based on analogous configuration of the guiding portion and the number of contacts of the interface housing and the corresponding nature of the multi-way connectors.

**[0062]** The ability to include an interface device within a connection of the type described in relation to the embodiments set out above can lead to efficiencies within the signal network with which the connection is to be used. For example, integrating particular functionality within an interface device removes the need for such functionality to be included within the network either side of the connector.

**[0063]** For example, a connector having a series of different signal attenuations applied to different connections or ports across the connector provides an effective and intuitive system by which a series of RF signals can be connected to a further stage in the network, where it is known that the different attenuation levels should be applied to different signals (for example, frequency channels) - the appropriate signal-carrying cable could simply be attached to the connector at the correct position corresponding to the desired attenuation level, rather than needing to employ a processor to identify the level to be applied.

**[0064]** The interface device 81 can also be removed from its surrounding connectors and replaced by a different interface device where functionality is to be changed, without requiring substantial reconfiguration of the signal network as a whole. Furthermore, each individual interface component 88 maybe be individually removed and replaced in order to alter the functionality of a single connection. For example, a single interface component 88 may be changed from a 1dB to a 2dB attenuation through removal and replacement.

**[0065]** In alternative embodiments, the ability to interchange connections of functionality of the interface device 81 is facilitated by adoption of a plug/socket system applied to the housing of the multi-way connectors 82, 83 and the interface devices. In other words, it is not necessary for connections to be changed or replaced on an individual basis, but groups of connections can be changed or replaced by changing one connector, with all connections served by that connector being changed or replaced together - this facilitates groupwise switching of interface components.

**[0066]** This substantially improves the ability to reconfigure the system, while maintaining advantages set out above, in terms of ensuring robustness, resistance to mechanical or thermal shocks and forces, and uniformity of connection of multiple signals. Industry-standard configurations can be used for the individual RF connections which are grouped within the multi-way connector housing, which enables predictable and industry-standard RF signal performance. Additionally, the structure of the housing of the connector is such that compatibility between different connectors is achieved if they share the common plug/socket architecture. This provides wide applicability to the connector, cable harness, connected system and interface devices of embodiments of the present invention.

**[0067]** The skilled person will appreciate that a variety of configurations are possible which fall within the scope of the claims, in dependence on the specific arrangement of connectors and interface devices. As such, features of embodiments described above, which are mutually

compatible, can be combined as further embodiments falling within the claim scope.

## Claims

1. A multi-way radio frequency, RF, connector comprising:

   a housing comprising a plurality of recesses for receiving each of a respective plurality of RF conductors to connect to a further plurality of RF conductors;
   a plurality of retention means, each accommodated within a respective one of the plurality of recesses, wherein each retention means is configured to retain the position of a respective one of the plurality of RF conductors with respect to the recess;
   a fastening means for fastening the housing to the housing of a further connector to secure the connection of each RF conductor to a respective one of the further plurality of RF conductors when retained by the further connector.

2. The connector of claim 1, wherein the housing further comprises a guiding portion surrounding the plurality of recesses, to guide the connection of the plurality of RF conductors with respect to the further plurality of further RF conductors.

3. The connector of claim 2, wherein the guiding portion comprises a plug to interface with a socket of the further connector.

4. The connector of claim 2, wherein the guiding portion comprises a socket to interface with a plug of the further connector.

5. The connector of any one of the preceding claims wherein the fastening means comprise a torque indication for indicating that the connector is fastened, via application of a predetermined torque to the fastening means, to the further connector with a predetermined tightness.

6. A radio-frequency, RF, cable harness comprising the connector of any of the preceding claims and a plurality of RF cables, wherein the plurality of RF cables are the plurality of RF conductors.

7. The cable harness of claim 6, wherein the plurality of RF cables comprise a respective plurality of subminiature type P, SMP, RF contacts for connecting to the further plurality of RF conductors.

8. A system comprising the connector of any one of claims 1 to 5, and the further connector, wherein the further connector is secured to the connector by a respective fastening means.

9. A system comprising the connector of any of claims 1 to 5 and a plurality of the further connectors, wherein each of the further connectors is secured to the connector by a respective fastening means,
   wherein the recesses of the connector are divided into groups each arranged to receive a group of RF conductors for connecting to respective plurality of RF conductors retained by a respective one of the plurality of further connectors.

10. An interface device configured to be coupled between a first and a second multi-way radio frequency, RF, connector, comprising:

    an interface housing comprising a plurality of interface components, wherein each interface component comprises a first portion configured to connect to a respective first RF conductor when retained by the first connector, and a second portion configured to connect to a respective second RF conductor when retained by the second connector, wherein the plurality of interface components are arranged to perform one or more functions on RF signals received from the first and/or second connectors;
    an interface fastening means for fastening the interface housing to the first and second connectors to secure the connection of each interface component.

11. The interface device of claim 9 wherein one or more functions comprise at least one of attenuation, RF loading, and signal passing.

12. The interface device of claim 10 or claim 11 wherein the interface housing comprises a first guiding portion surrounding the first portions of the interface components and a second guiding portion surrounding the second portions of the interface components, the first and second guiding portions configured to guide the coupling of the interface device to the first and second connectors respectively.

13. The interface device of any one of claims 10 to claim 12 wherein the first and second portions of the interface components comprise a plurality of sub-miniature push-on, SMP, RF contacts.

14. The system of claim 8, further comprising the interface device of any one of claims 10 to 13, wherein the connector is the first connector and the further connector is the second connector.

15. The system of claim 9, further comprising a plurality of interface devices of any one of claims 10 to 13,

wherein the connector is the first connector and the plurality of further connectors is a plurality of second connectors, and each of the plurality of interface devices is arranged to couple the first connector to a respective one of the plurality of second connectors.

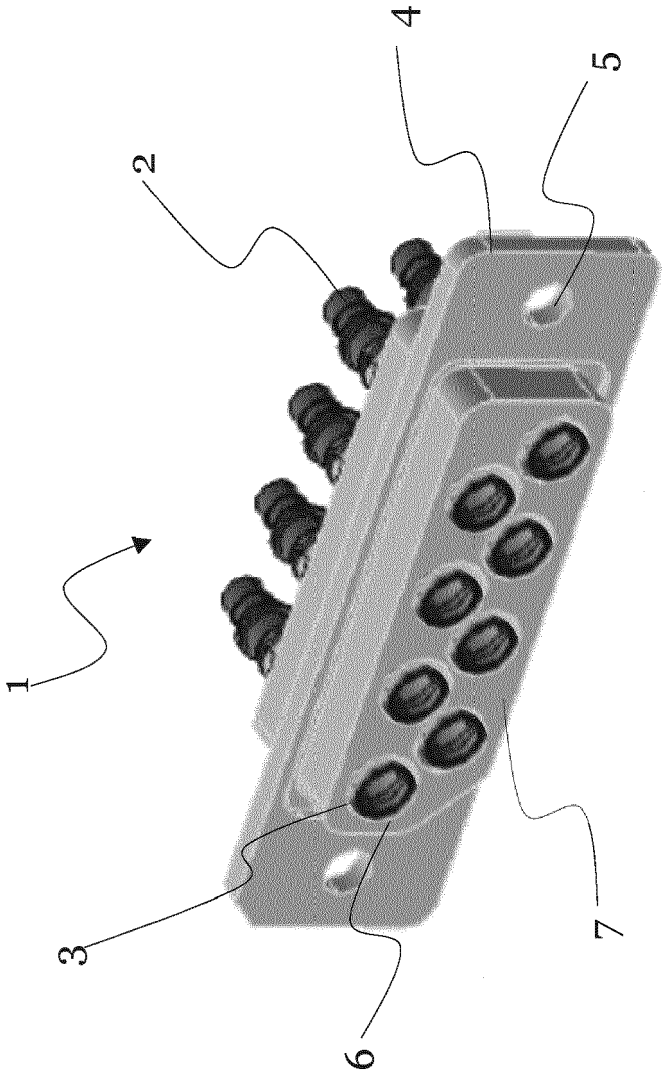


Figure 1

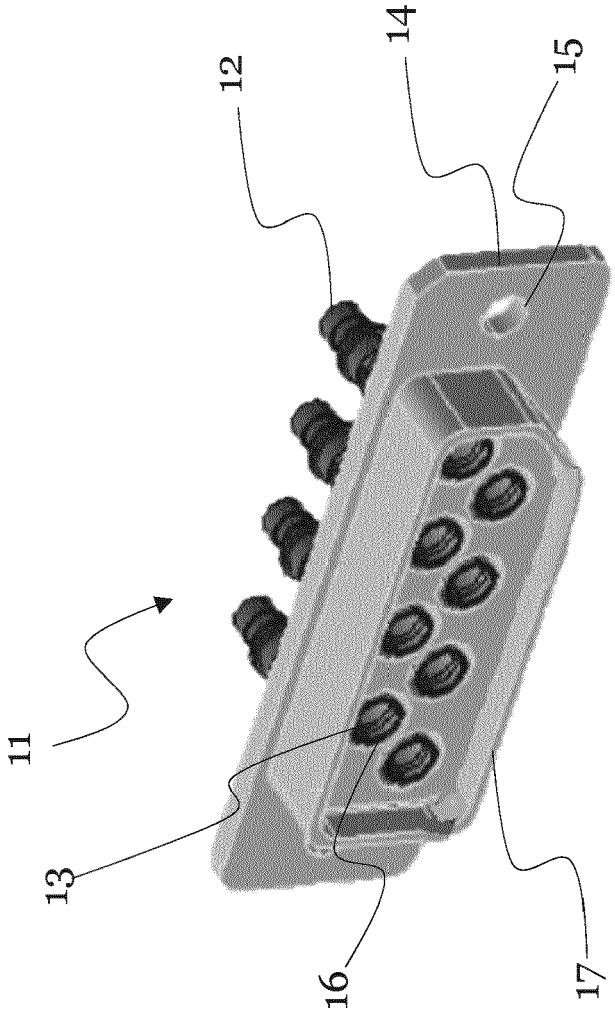


Figure 2

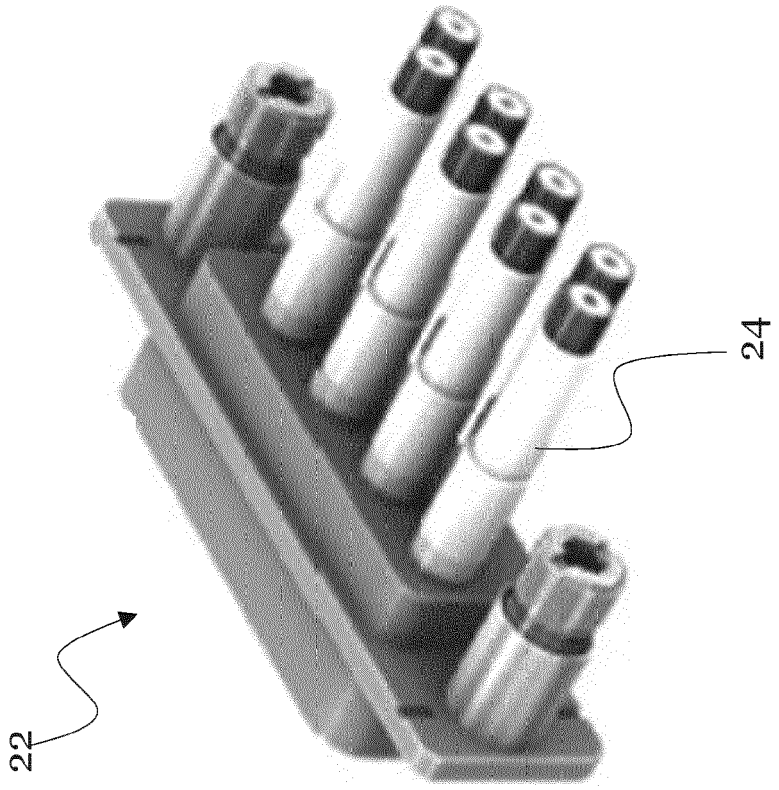


Figure 3b

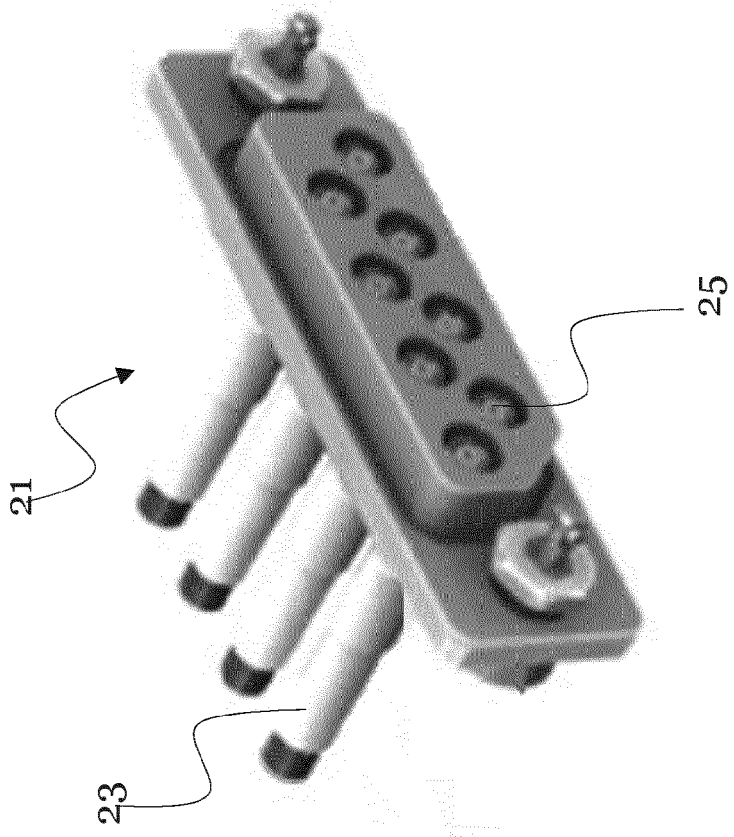


Figure 3a

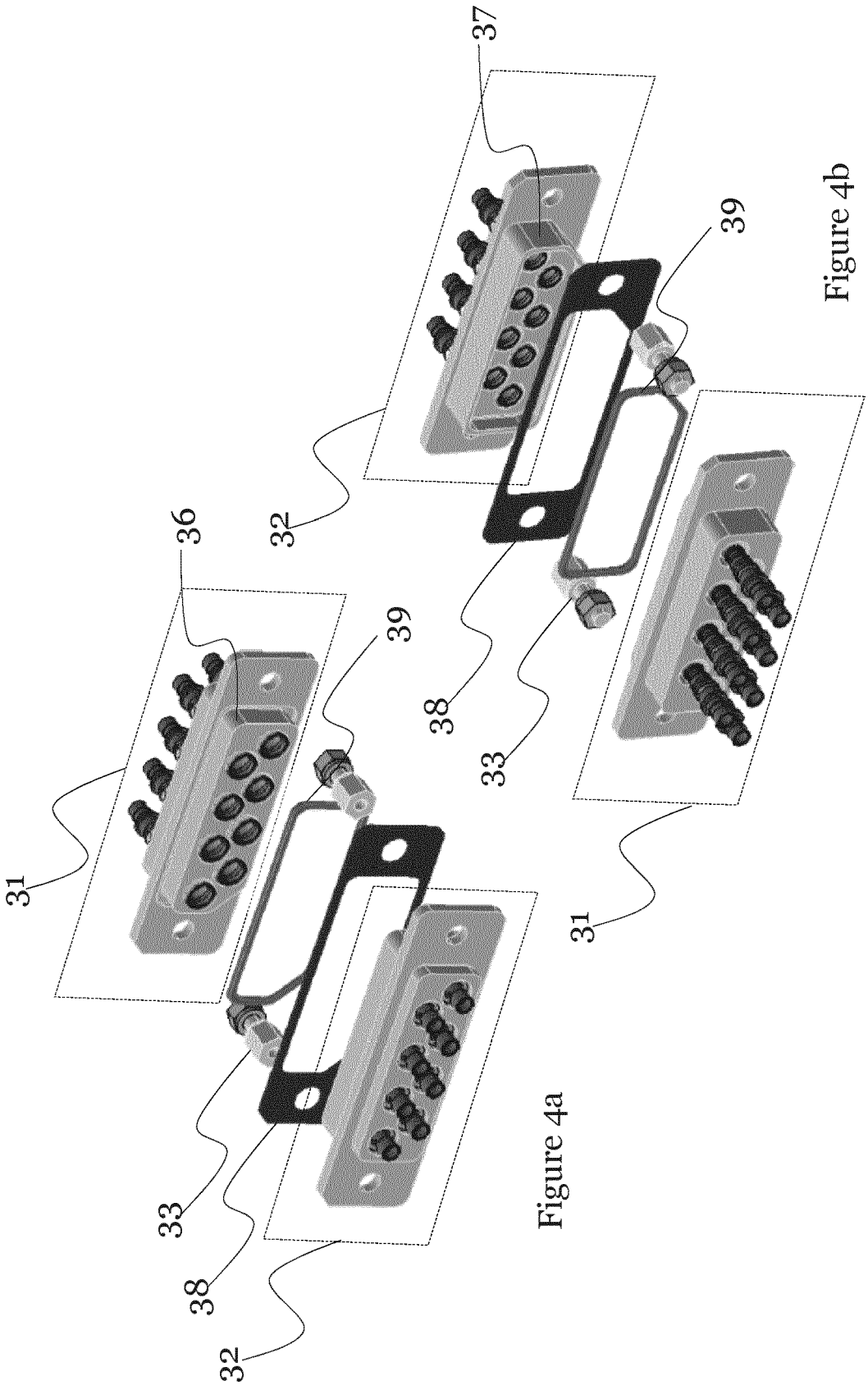


Figure 4a

Figure 4b

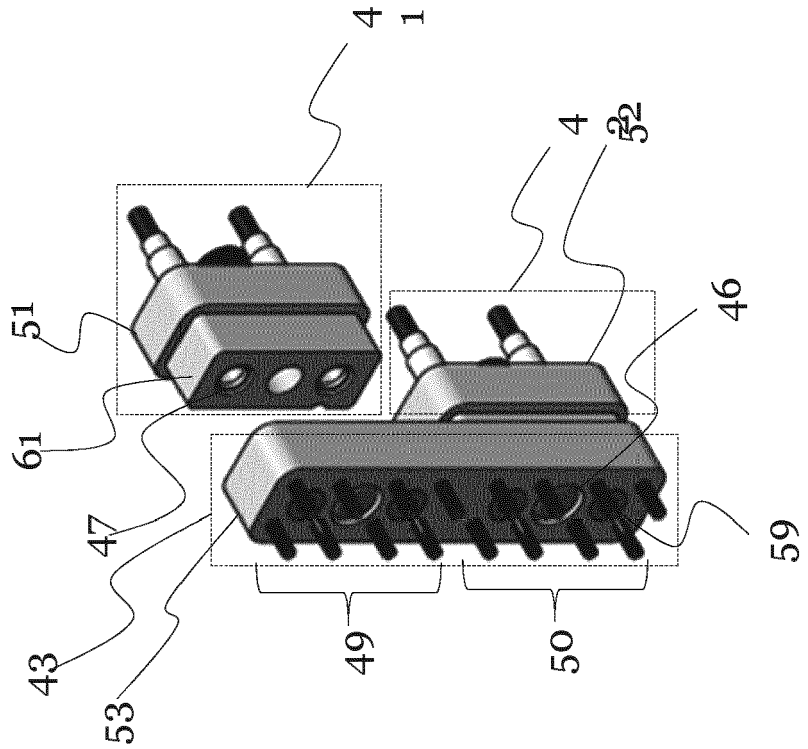


Figure 5b

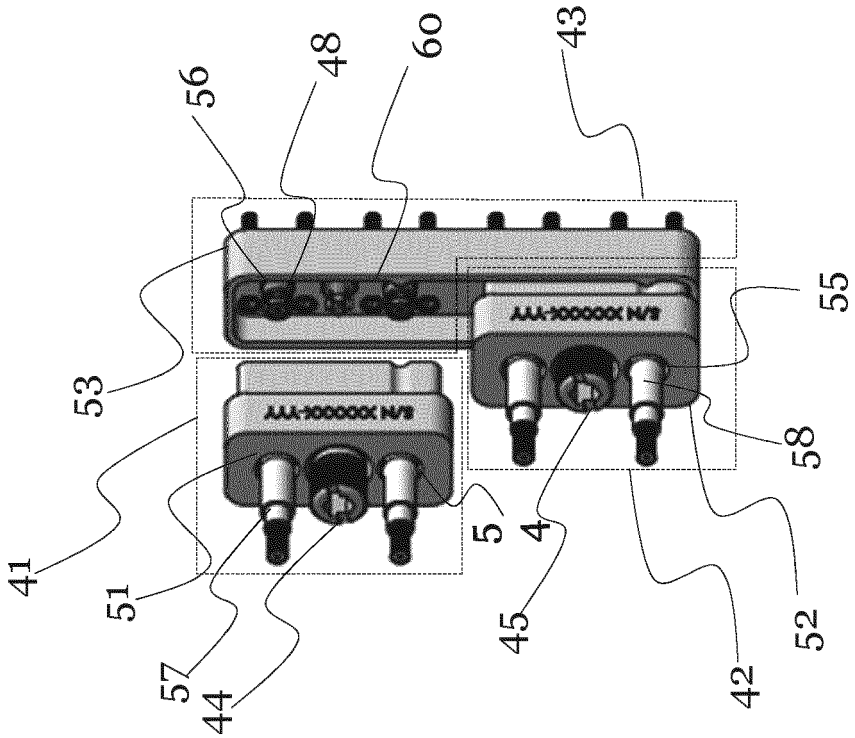


Figure 5a

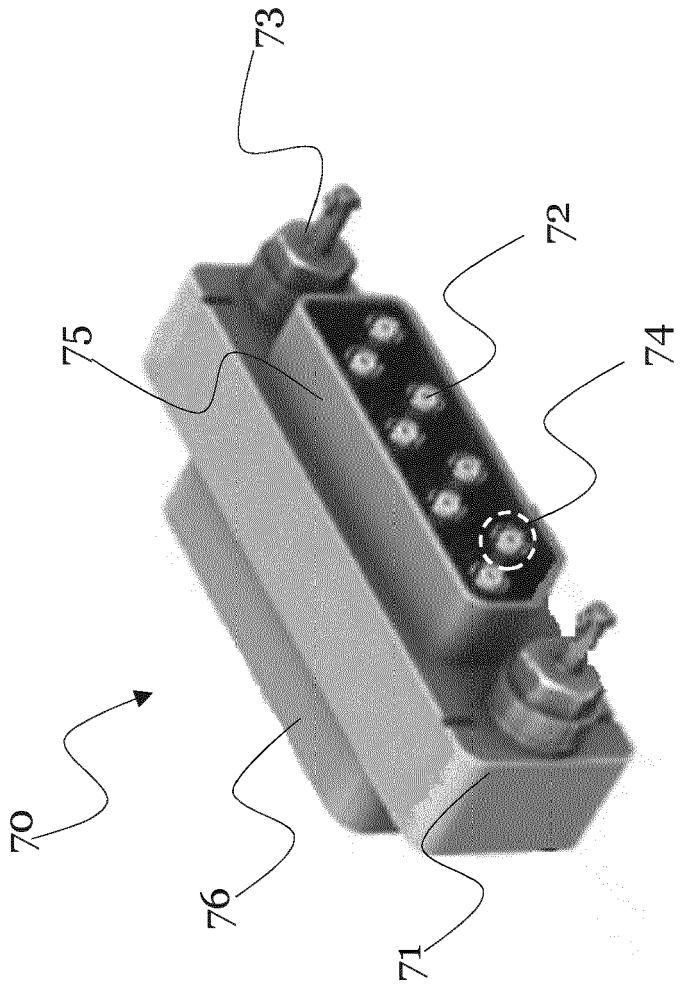


Figure 6

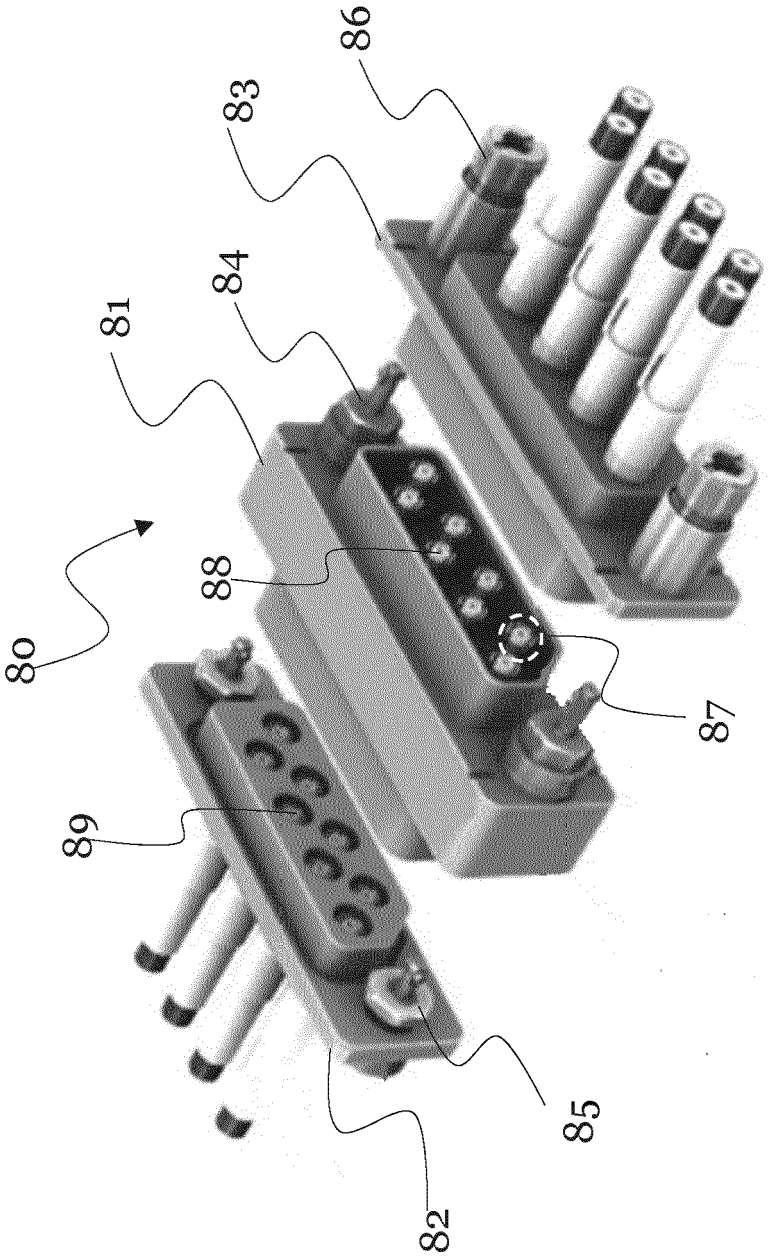


Figure 7

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# EUROPEAN SEARCH REPORT

Application Number
EP 22 18 0844

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| A | * abstract; figures 26-27 * | 1-8,14 | ADD. |
| X | EP 0 003 162 A1 (AMP INC [US]) 25 July 1979 (1979-07-25) | 10-12 | H01R103/00 H01R101/00 |
| Y | * figures 1,2 * | 13-15 | |
| A | * page 3, line 22 - page 3, line 25 * | 1-9 | |
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TECHNICAL FIELDS SEARCHED (IPC)

H01R

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 20 January 2023 | Skaloumpakas, K |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
EP 22 18 0844

## CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

**see sheet B**

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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## LACK OF UNITY OF INVENTION
## SHEET B

Application Number
EP 22 18 0844

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-9(completely); 14, 15(partially)

   A multi-way radio frequency, RF, connector with fastening means.

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2. claims: 10-13(completely); 14, 15(partially)

   An interface device with interface components arranged to perform one or more functions on RF signals

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 18 0844

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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20-01-2023

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82