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(54) A RADIO FREQUENCY FILTER COMPRISING A CHAMBER, AND A METHOD OF FILTERING

(57) A radio frequency filter comprising a resonator chamber comprising a top wall, a first wall, a second wall opposite said first wall, side walls, and end walls, in which a radio frequency feeding member is disposed at least substantially within the chamber, the feeding member including an end portion which extends into a gap in the top wall so as to electromagnetically connect to a dielectric layer lying over the gap; in use, electricity being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter.

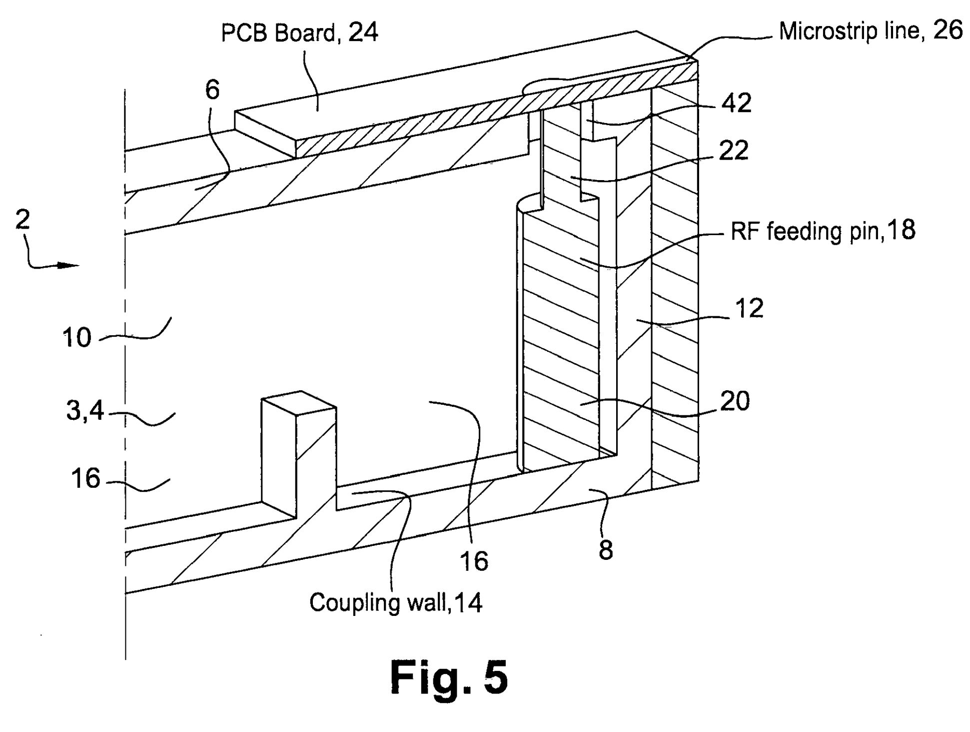

Fig. 5

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Description

Field of the Invention

[0001] The present invention relates to a radio frequency filter and to a method of radio frequency filtering.

Description of the Related Art

[0002] The connection of a power amplifier (PA) to a Radio-Frequency (RF) filter is important in any telecommunications system. This connection needs to be low loss, as the power output of the power amplifier can be of the order of tens of watts and so any loss at this connection will significantly impact the overall loss of the system.

[0003] One known approach is described in Chinese Utility Model Publication CN201946726 (U).

Summary

[0004] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0005] An example of the present invention is a radio frequency filter comprising a chamber comprising a first wall, a second wall opposite said first wall, side walls, and end walls,
in which a radio frequency feeding member is disposed at least substantially within the chamber,
the feeding member including an end portion which extends into a gap in the top wall so as to connect to a dielectric layer lying over the gap;
in use, a radio frequency signal being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter or being coupled out of the feeding member via the dielectric layer so as to be electromagnetically coupled from the filter.

[0006] Preferably said end portion connects to the dielectric layer by being in contact with the dielectric layer.

[0007] Preferably said end portion connects to the dielectric layer by being in proximity with the dielectric layer. For example there may be an air space between the end portion and dielectric layer.

[0008] Preferably the dielectric layer has a metal layer on its surface facing towards the chamber, in a region the metal layer being at least partially removed so that the end portion of the feeding member electrically connects to the dielectric layer in that region. Preferably in said region the metal layer has been at least partially etched away.

[0009] Preferably a conductor is provided on a second surface of the dielectric layer, said second surface facing away from the chamber; and in which for electromagnetic coupling via the dielectric layer into or from the feeding member, the conductor has an end portion opposite said region. Preferably the dielectric layer, the conductor and the bottom metal layer including said region, comprise a Printed Circuit Board, PCB. Preferably the conductor was produced by etching away at a metal layer on the top surface of the dielectric layer.

[0010] Preferably the end portion of the conductor, the gap in the top wall and the region for contact with the dielectric layer lie on a shared axis. Preferably the shared axis is perpendicular to the plane of the top wall.

[0011] Preferably the conductor is a microstrip line.

[0012] Preferably the end portion of the conductor is at least one of at least partially circular and at least partially rectangular.

[0013] Preferably the gap is a hole having an inside surface and the end portion of the feeding member is of a size so as to fit into the cylindrical hole without touching its inside surface. For example, the gap may be a cylindrical hole having an inside surface and the end portion of the feeding member is cylindrical having a diameter so as to fit into the cylindrical hole without touching its inside surface.

[0014] Preferably the feeding member has a body portion, and the end portion of the feeding member is a head portion which is narrower than the body portion.

[0015] Furthermore, preferably the chamber houses at least one resonator post.

[0016] Furthermore, preferably the first wall is a top wall and the second wall is a bottom wall.

[0017] Furthermore, preferably the feeding member is a feeding pin. Furthermore, preferably the feeding member is metallic or of some other other electrically conductive material.

[0018] The present invention also relates to method of radio frequency filtering comprising passing a signal for filtering through a radio frequency filter comprising a chamber comprising a first wall, a second wall opposite said first wall, side walls, and end walls;
in which a radio frequency feeding member is disposed at least substantially within the chamber;
the feeding member including an end portion which extends into a gap in the top wall so as to contact a dielectric layer lying over the gap;
in use, a radio frequency signal being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter or being coupled out of the feeding member via the dielectric layer so as to be electromagnetically coupled from the filter.

[0019] Preferred embodiments provide non-galvanic Printed Circuit Board (PCB) feeding of Radio Frequency (RF) cavity filters. Preferred embodiments provide a low loss solution.

[0020] In preferred embodiments, a PCB is etched on its top side to provide a microstrip line ending in a circular metal disc.

[0021] In preferred embodiments, on the bottom side of the PCB, the metal is totally etched away (or patterned in a way that some metal has been removed) in a circular disc region below, for example exactly below, the microstrip line end on the top side of the PCB. This region is a gap in the metal layer allows electromagnetic coupling of signals between (to and/or from) the filter cavity and the microstrip line.

[0022] In preferred embodiments, a feeding pin extends through the filter housing through a gap so as to directly contact that region on the bottom side of the PCB, so allowing electromagnetic energy to be coupled into the resonator cavity from the microstrip line on the top of the PCB, thereby enabling filter operation.

[0023] Preferred embodiments provide a solution of good reliability. Preferred embodiments provide a simple way of RF coupling into an RF filter.

[0024] Preferred embodiments provide a filter assembly with low Passive Inter-Modulation (PIM).

[0025] Preferred embodiments provide capacitive coupling, which is especially suitable for bandwidth limited devices, for example RF filters with one or more resonator cavities.

[0026] Preferred embodiments have technical advantages compared to Chinese Utility Model Publication CN201946726 (U). For example, there is no need for a screw to ensure coupling between an external conductor and an RF feeding pin which is inside the cavity. There is no need for a galvanic connection between a PCB and the feeding pin; in consequence reliability and Passive Inter-Modulation (PIM) performance is enhanced. There is no need for an EMC gasket. In preferred embodiments there may be no negative impact on key filter performance indicators, such as bandwidth and power handling, and preferred embodiments are resilient to many mechanical variations in components, such as PCB dimensions.

Brief Description of the Drawings

[0027] Embodiments of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 (PRIOR ART) is a diagram illustrating a sectional side view of a known Printed Circuit Board (PCB) feed for an RF filter;

Figure 2 (PRIOR ART) is a diagram illustrating a top view of the known PCB feed shown in Figure 1;

Figure 3 is a diagram illustrating an oblique sectional view of a resonator assembly according to a first embodiment of the invention, including a PCB, and a resonator chamber in which in use there are resonators (not shown);

Figure 4 consists of (a) a top view, and (b) a bottom view, of the PCB used in the resonator assembly shown in Figure 3;

Figure 5 is an oblique cross-sectional view of the resonator assembly shown in Figures 3 and 4,

Figure 6 is an oblique cross-sectional view of the resonator assembly shown in Figures 3 to 5 in a different plane and with one of the resonators shown,

Figure 7 is an oblique cross-sectional view of the resonator assembly shown in Figures 3 to 6 in a different plane and with two of the resonators shown, and tuning screws and a coupling screw shown;

Figure 8 is a cross-sectional view of a resonator assembly ("3-pole filter") according to a second embodiment of the invention; and

Figure 9 is an oblique view showing in more detail the resonator assembly shown in Figure 8.

Detailed Description

[0028] When considering the known filter described in Chinese Utility Model Publication CN201946726 (U) and shown in Figures 1 and 2, the inventors realised that in this known approach the feed to the RF filter through the Printed Circuit Board (PCB) is galvanic and requires an RF feeding pin to be secured with a screw, or a solder connection, on the top of the PCB, as shown in Figure 1. For acceptably low loss and low Passive Inter-Modulation (PIM) the screw needs to be either silver or plated with a metal other than steel. Steel screws cannot be used unless plated with another metal due to the high RF losses associated with steel.

[0029] Furthermore, as shown in Figure 1, an Electro-Magnetic Compatibility (EMC) gasket is used to ensure a good connection between the ground plane of the PCB and the metal top cover of the filter. This gasket results in increased height, and hence volume, of the filter. Figure 2 is a top view of this filter showing the feed made up of the feeding pin and the connector to the feeding pin on the top surface of the PCB.

[0030] The inventors realised that an improved approach was possible. We turn now to describing an embodiment as shown in Figures 3 to 6.

[0031] As shown in Figure 3, a Radio Frequency filter 2 is provided comprising a resonant chamber 3 which includes a filter cavity 4 defined by a top wall 6, a bottom wall 8, side walls 10 and end walls 12. Within the filter cavity 4 are coupling walls 14 of less than full height which separate resonator cavities 16 within the filter cavity 4. It will, of course, be understood that Figure 3 shows the end portion of the filter 2 rather than the whole filter. Within each resonator cavity 16 there is a resonator post (not shown) of known type.

[0032] There is an RF feeding pin 18 in the filter cavity 4 having a cylindrical body portion 20 and a cylindrical head portion 22 of smaller diameter that the cylindrical body portion 20. The RF feeding pin 18 is made of metal, in other words, metallic.

[0033] As shown in Figure 3, there is a Printed Circuit Board (PCB) 24 mounted on the top wall 6 of the filter 2. On part of the PCB 24 a microstrip line 26 is etched.

[0034] As shown in Figure 4, the microstrip line is etched onto the top surface 28 of the PCB 24. The microstrip line 12 ends in a substantially circular metal disc-portion 30. On the bottom surface 32 of the PCB 24, there is a metal base layer 36, but in a region 34 that includes exactly below the circular disc-portion 30, the metal is etched away so as to expose the dielectric material of the PCB for the purpose of electromagnetic coupling. In this embodiment, the metal is etched away completely in the region 34, but in an otherwise similar embodiment (not shown) the metal is partially removed for example with an etching pattern.

[0035] The etched region 34 (in other words exposed dielectric region) allows electromagnetic coupling of a signal into the filter cavity 4 via the microstrip line 26 and from the filter cavity 4 to the microstrip line 26.

[0036] As shown in Figure 4 , the PCB includes a small area 36 on its bottom surface 32 also etched and provided with a hole 38 for a tuning screw (not shown). The PCB 24 also has multiple holes 40 for holding screws (not shown).

[0037] Figure 5 is another cross-section having a different but parallel cutting plane to that of Figure 3.

[0038] As shown in Figure 5, the head portion 22 of the feeding pin 18 lies directly under a PCB 24. The etched region 34 in the metal base layer 36 of the PCB 24 allows electromagnetic coupling between the disc-portion 30 of the microstrip line 26 and the head portion 22 of the RF feeding pin 18. The purpose of the RF feeding pin 18 is two-fold. In a filter made up of multiple resonator cavities 16 in a row, an RF feeding pin couples energy to or from the resonator cavity 16 at the end of the row (as shown in Figures 3 to 5). It also couples that electromagnetic energy to or from the microwave strip line 26.

[0039] This coupling is achieved by the top wall 6 including an opening 42 through which the head portion 22 of the RF feeding pin 18 is in direct contact with the etched region 34 of the PCB 24, so as to contact the exposed dielectric of the PCB 26, thereby coupling the disc-portion 30 of the microstrip line 26. This enables the filter to correctly operate. (In an alternative embodiment there may be an air space between the head portion of the RF feeding pin and etched region of the PCB, the air space being narrow enough to allow electromagnetic coupling).

[0040] In this example, the amount of coupling depends on the size of the opening 42 in the top wall 6 (in other words in the housing), and also the width of the microstrip line 26, for example in particular its end disc portion 30. Both this size and this width are selected during the stage of designing the filter 2.

[0041] Figure 6 is a further oblique sectional view of the end portion of the filter 2, being a cross-section having a different but parallel cutting plane to that of Figures 3 and 5. In Figure 6 a cylindrical resonator post 44, is shown. The RF feeding pin 18 is also shown.

[0042] Figure 7 is a further oblique sectional view of the end portion filter 2. As shown in Figure 7, there are multiple resonator posts 44 each having a hollowed portion 46 and a solid portion 48. The resonator post 44 nearest RF feeding pin 18 is connected directly to the RF feeding pin 18 by a Direct Current (DC) connection 50.

[0043] As shown in Figure 7, coupling screws 52 go through the coupling screw holes 40 of the PCB 24 and a tuning screw 54 goes through the corresponding hole 38 in th PCB. Theses coupling screws 52 and tuning screw 54 are required to tune the electrical response of the filter 2 and are effectively incorporated in the PCB 24.

[0044] As shown in Figures 8 and 9, in this example, the filter 2 is a 3 pole filter, in other wards having three resonator cavities 16. The filter 2 includes at one end 56, the end portion shown in Figures 3 and 5 to 7, and a known feeding pin 58 at the other end 60.

[0045] Although other materials and dimensions are possible, this particular example includes the following:

The dielectric material of the PCB 24 (that lies above its metal base layer 36) has a thickness of 0.762mm;
The diameter of the head portion 22 of the RF feeding pin 18 is 4mm;
The corresponding circular end portion 30 of the microstrip line 24 has a diameter of 4mm;
The etched-away region 34 in the metal base layer 36 on the bottom surface 32 of the PCB 24 is circular having a diameter of 8mm;
The corresponding opening 22 in the top wall 6 has a diameter of 8mm;
In this example, the dielectric material of the PCB 24 is FR-4 glass epoxy, which is a high pressure thermoset composite material composed of woven fibreglass cloth in an epoxy resin binder.

[0046] In other examples, the filter can have more, or less, than three resonator cavities, in other words, more, or less, than 3 poles.

[0047] In other embodiments, the RF feeding pin consists of one or more metal cylinders of different diameters to each other.

[0048] In some other examples, the dielectric material of the PCB 24 is RO4350B laminate as sold by Rogers Corporation; for further details of which, please see: https://www.rogerscorp.com/acs/products/55/R04350B-Laminates.aspx

[0049] In some other embodiments, the end portion of the microstrip line is of a different shape than the circular end portion 30, for example rectangular, hexagonal or any other shape.

[0050] The present invention may be embodied in other specific forms without departing from its essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0051] A person skilled in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Some embodiments relate to program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computerexecutable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. Some embodiments involve computers programmed to perform said steps of the above-described methods.

Claims

1. A radio frequency filter comprising a chamber comprising a first wall, a second wall opposite said first wall, side walls, and end walls,

in which a radio frequency feeding member is disposed at least substantially within the chamber, the feeding member including an end portion which extends into a gap in the first wall so as to electromagnetically connect to a dielectric layer lying over the gap;
in use, a radio frequency signal being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter or being coupled out of the feeding member via the dielectric layer so as to be electromagnetically coupled from the filter.

2. A radio frequency filter according to claim 1, in which said end portion electromagnetically connects to the dielectric layer by being in contact with the dielectric layer.

3. A radio frequency filter according to claim 1 or claim 2, in which said end portion electromagnetically connects to the dielectric layer by being in proximity with the dielectric layer.

4. A radio frequency filter according to any preceding claim, in which the dielectric layer has a metal layer on its surface facing towards the chamber, in a region the metal layer being at least partially removed so that the end portion of the feeding member connects to the dielectric layer in that region.

5. A radio frequency filter according to claim 4, in which in said region the metal layer has been at least partially etched away.

6. A radio frequency filter according to claim 4 or claim 5, in which a conductor is provided on a second surface of the dielectric layer, said second surface facing away from the chamber; and in which for electromagnetic coupling via the dielectric layer into or from the feeding member, the conductor has an end portion opposite said region.

7. A radio frequency filter according to claim 6, in which the dielectric layer, the conductor and the bottom metal layer including said region, together comprise a Printed Circuit Board, PCB.

8. A radio frequency filter according to claim 6 or claim 7, in which the conductor was produced by etching away at a metal layer on the top surface of the dielectric layer.

9. A radio frequency filter according to any of claims 6 to 8, in which the end portion of the conductor, the gap in the top wall and the region for contact with the dielectric layer lie on a shared axis.

10. A radio frequency filter according to claim 8, in which the shared axis is perpendicular to the plane of the top wall.

11. A radio frequency filter according to any of claims 6 to 10, in which the conductor is a microstrip line.

12. A radio frequency filter according to any of claims 6 to 11, in which the end portion of the conductor is at least one of at least partially circular and at least partially rectangular.

13. A radio frequency filter according to any preceding claim, in which the gap is a hole having an inside surface and the end portion of the feeding member is of a size so as to fit into the cylindrical hole without touching its inside surface.

14. A radio frequency filter according to any preceding claim, in which the feeding member has a body portion, and the end portion of the feeding member is a head portion which is narrower than the body portion.

15. A method of radio frequency filtering comprising passing a signal for filtering through a radio frequency filter comprising a chamber comprising a first wall, a second wall opposite said first wall, side walls, and end walls;
in which a radio frequency feeding member is disposed at least substantially within the chamber;
the feeding member including an end portion which extends into a gap in the first wall so as to electromagnetically connect to a dielectric layer lying over the gap;
in use, a radio frequency signal being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter or being coupled out of the feeding member via the dielectric layer so as to be electromagnetically coupled from the filter.

Amended claims in accordance with Rule 137(2) EPC.

1. A radio frequency filter (2) comprising a chamber (3) comprising a first wall (6), a second wall (8) opposite said first wall, side walls (10), and end walls (12),

in which a radio frequency feeding member (18) is disposed at least substantially within the chamber, the feeding member including an end portion (22) which extends into a gap (42) in the first wall (6) so as to electromagnetically connect to a dielectric layer (24) lying over the gap;
in use, a radio frequency signal being coupled into the feeding member (18) via the dielectric layer (24) so as to be electromagnetically coupled into the filter or being coupled out of the feeding member (18) via the dielectric layer (24) so as to be electromagnetically coupled from the filter;
characterised in that said end portion (22) electromagnetically connects to the dielectric layer (24) by being in contact with the dielectric layer.

2. A radio frequency filter according to claim 1 or claim 2, in which said end portion (22) electromagnetically connects to the dielectric layer (24) by being in proximity with the dielectric layer.

3. A radio frequency filter according to any preceding claim, in which the dielectric layer has a metal layer on its surface facing towards the chamber, in a region (34) the metal layer being at least partially removed so that the end portion (22) of the feeding member (18) connects to the dielectric layer (24) in that region.

4. A radio frequency filter according to claim 3, in which in said region the metal layer has been at least partially etched away.

5. A radio frequency filter according to claim 3 or claim 4, in which a conductor (26) is provided on a second surface of the dielectric layer (24), said second surface facing away from the chamber; and in which for electromagnetic coupling via the dielectric layer (24) into or from the feeding member, the conductor has an end portion (30) opposite said region.

6. A radio frequency filter according to claim 5, in which the dielectric layer, the conductor and the bottom metal layer including said region, together comprise a Printed Circuit Board, PCB.

7. A radio frequency filter according to claim 5 or claim 6, in which the conductor (26) was produced by etching away at a metal layer on the top surface of the dielectric layer.

8. A radio frequency filter according to any of claims 5 to 6, in which the end portion of the conductor (30), the gap (42) in the top wall and the region (34) for contact with the dielectric layer lie on a shared axis.

9. A radio frequency filter according to claim 7, in which the shared axis is perpendicular to the plane of the top wall.

10. A radio frequency filter according to any of claims 5 to 9, in which the conductor (26) is a microstrip line.

11. A radio frequency filter according to any of claims 5 to 10, in which the end portion (30) of the conductor (26) is at least one of at least partially circular and at least partially rectangular.

12. A radio frequency filter according to any preceding claim, in which the gap (42) is a hole having an inside surface and the end portion (22) of the feeding member (18) is of a size so as to fit into the cylindrical hole without touching its inside surface.

13. A radio frequency filter according to any preceding claim, in which the feeding member (18) has a body portion, and the end portion (22) of the feeding member is a head portion which is narrower than the body portion.

14. A method of radio frequency filtering comprising passing a signal for filtering through a radio frequency filter (2) comprising a chamber (3) comprising a first wall (6), a second wall (8) opposite said first wall, side walls (10), and end walls (12);

in which a radio frequency feeding member (18)is disposed at least substantially within the chamber;
the feeding member including an end portion (22) which extends into a gap in the first wall so as to electromagnetically connect to a dielectric layer (24) lying over the gap;
in use, a radio frequency signal being coupled into the feeding member via the dielectric layer so as to be electromagnetically coupled into the filter or being coupled out of the feeding member via the dielectric layer so as to be electromagnetically coupled from the filter;
characterised in that said end portion (22) electrically connects to the dielectric layer (24) by being in contact with the dielectric layer.

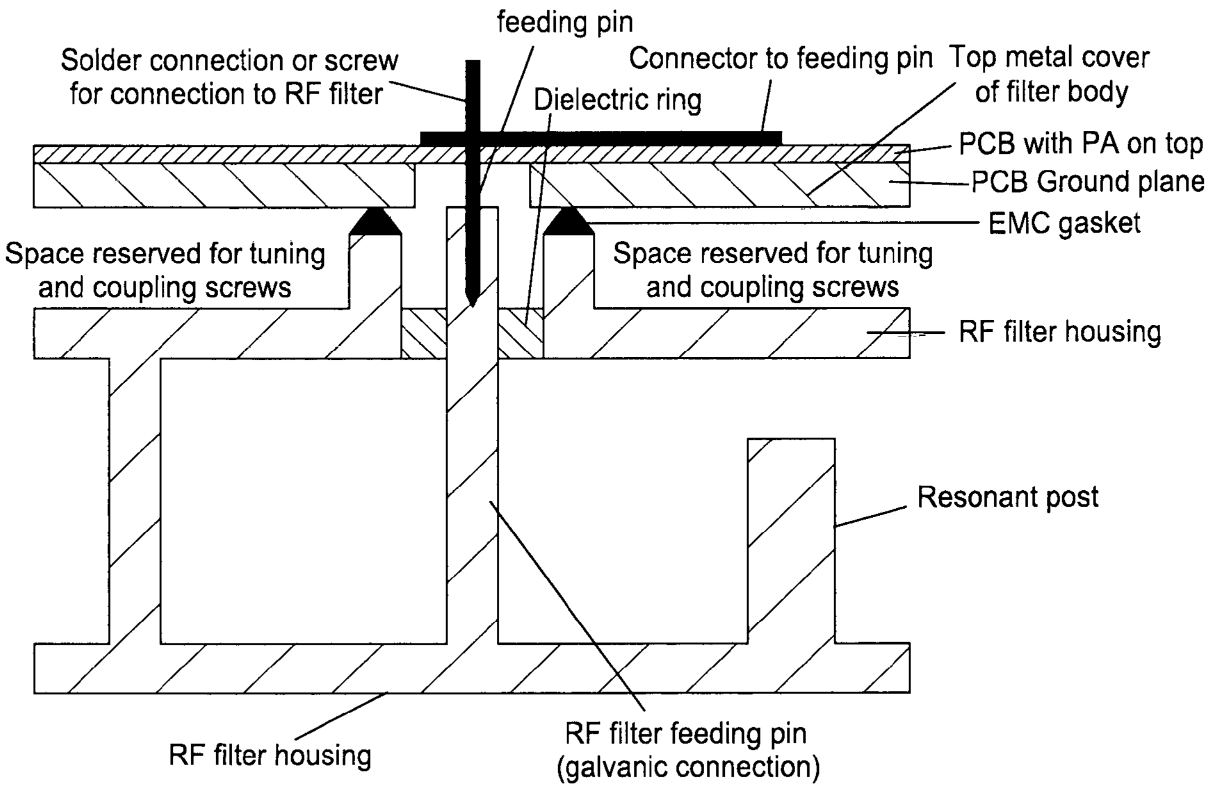

Fig. 1

PRIOR ART

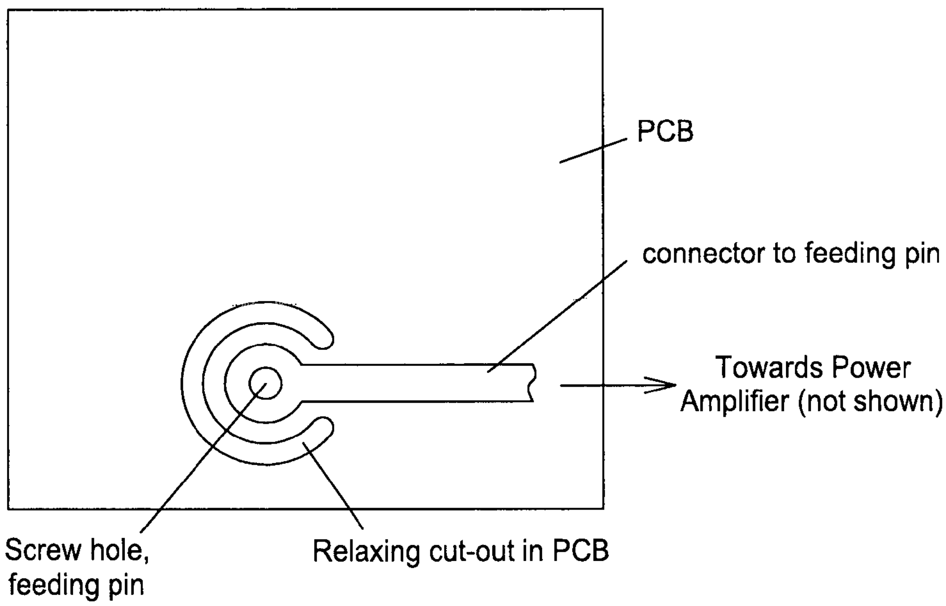

Fig. 2

PRIOR ART

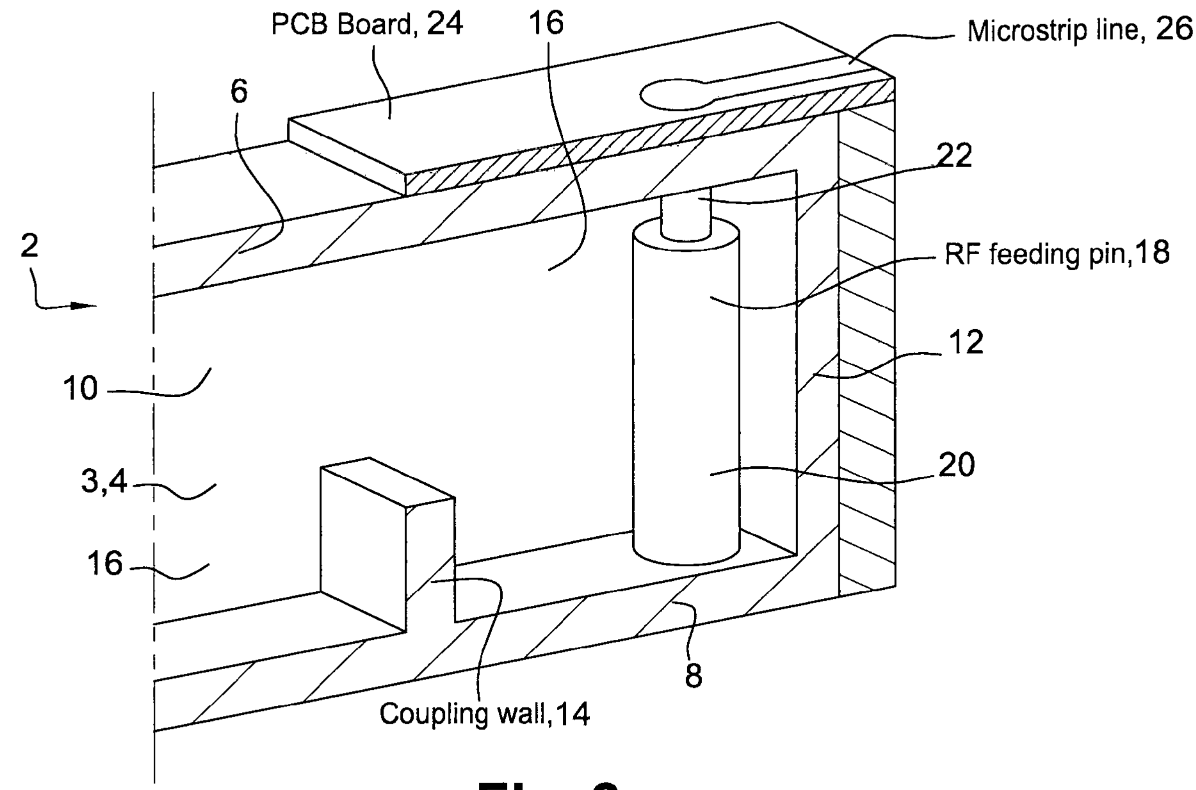
PCB Board, 24
16
Microstrip line, 26
6
22
2
RF feeding pin,18
12
10
3,4
20
16
8
Coupling wall,14

Fig. 3

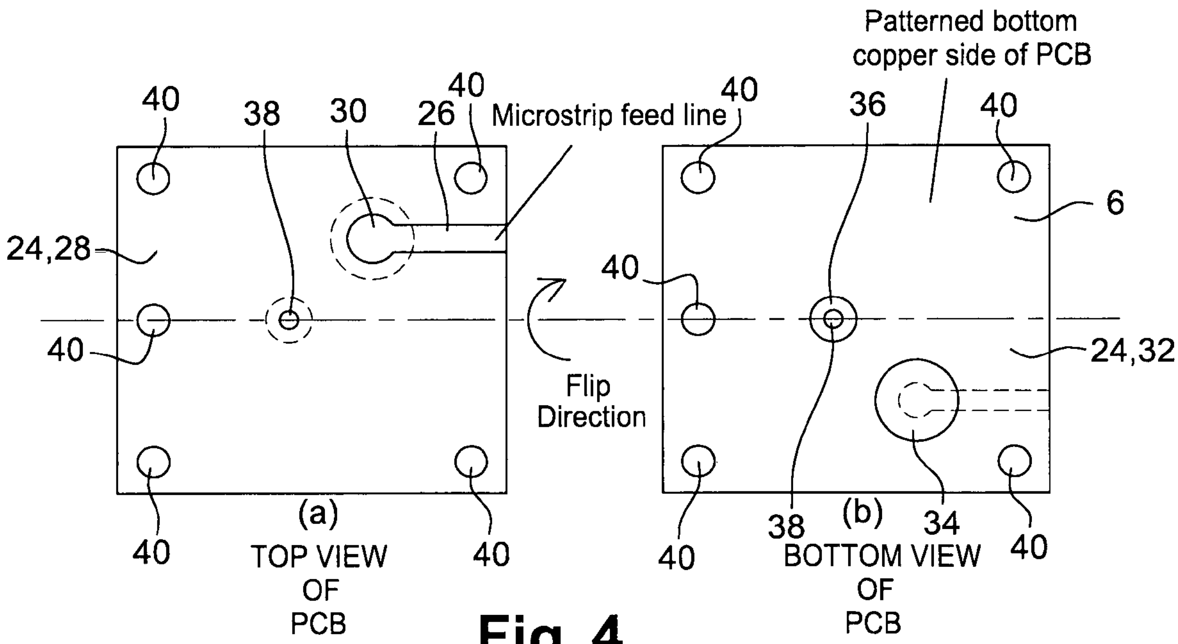
Patterned bottom
copper side of PCB
40
38
30
26
40
Microstrip feed line
40
36
40
6
24,28
40
40
24,32
Flip
Direction
40
40
40
38
34
40
(a)
TOP VIEW
OF
PCB
(b)
BOTTOM VIEW
OF
PCB

Fig. 4

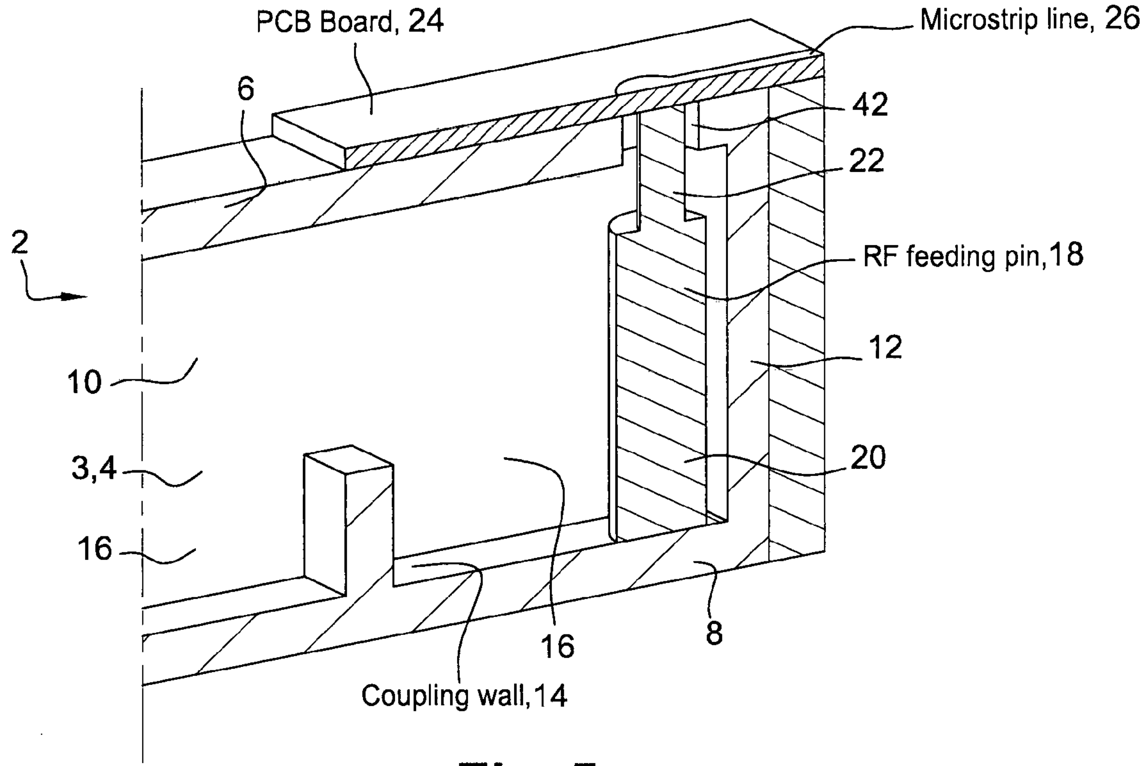
PCB Board, 24
Microstrip line, 26
6
42
22
2
RF feeding pin,18
12
10
3,4
20
16
16
8
Coupling wall,14

Fig. 5

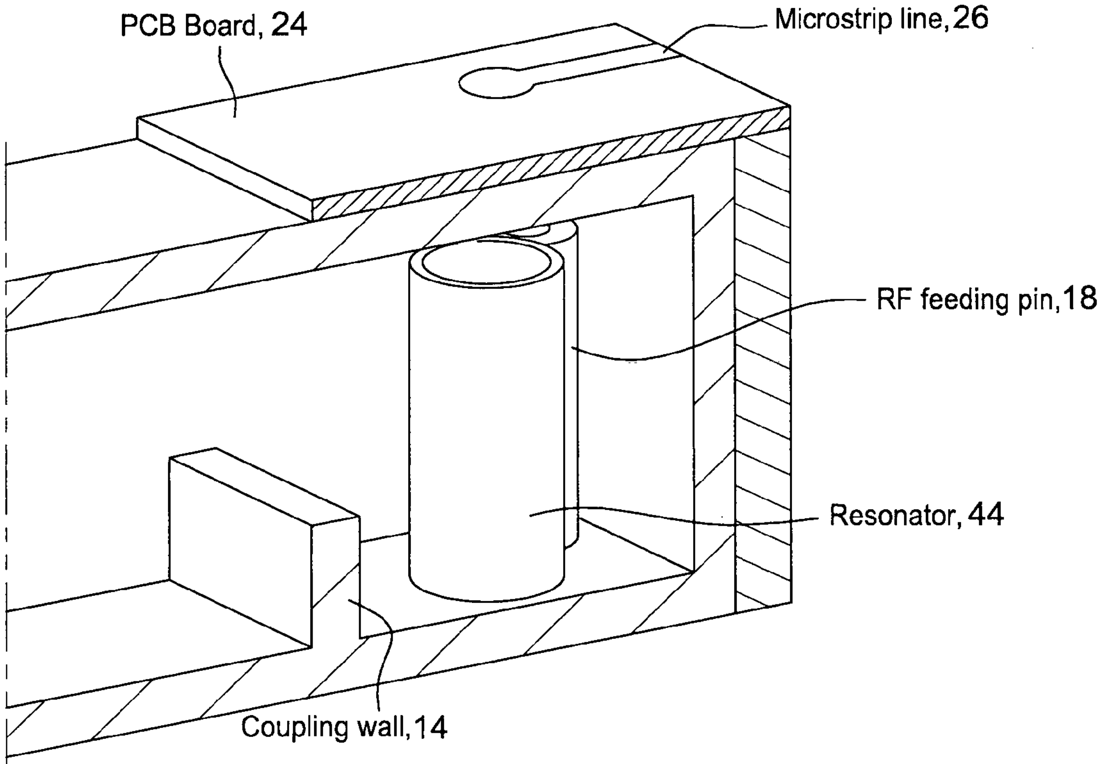
PCB Board, 24
Microstrip line,26
RF feeding pin,18
Resonator, 44
Coupling wall,14

Fig. 6

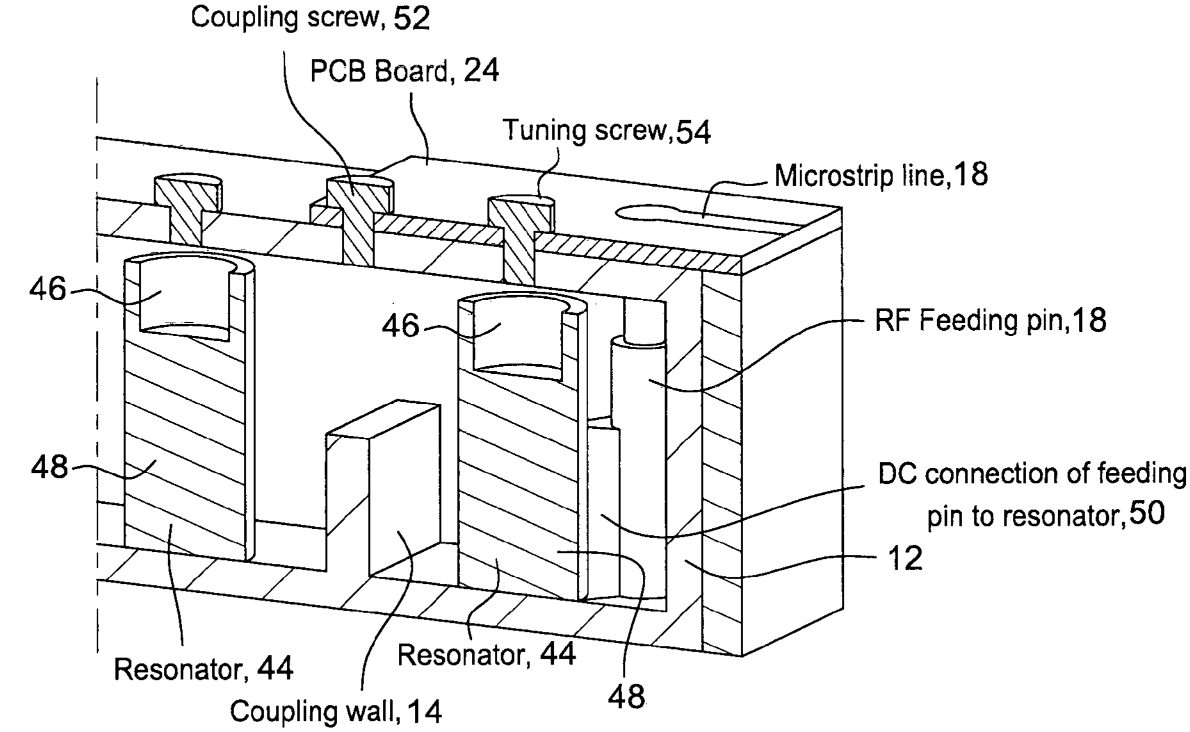
Coupling screw, 52
PCB Board, 24
Tuning screw,54
Microstrip line,18
46
46
RF Feeding pin,18
48
DC connection of feeding pin to resonator,50
12
Resonator, 44
Resonator, 44
Coupling wall, 14
48

Fig. 7

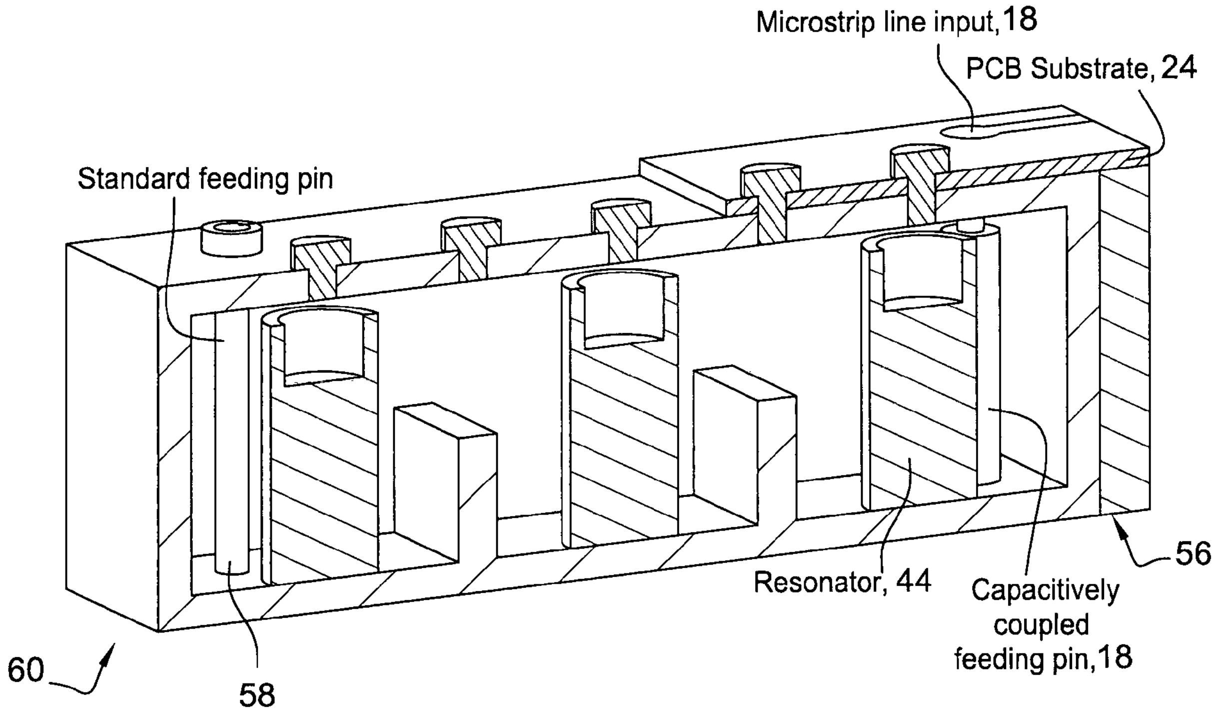
Microstrip line input,18
PCB Substrate, 24
Standard feeding pin
56
Resonator, 44
Capacitively coupled feeding pin,18
60
58

Fig. 8

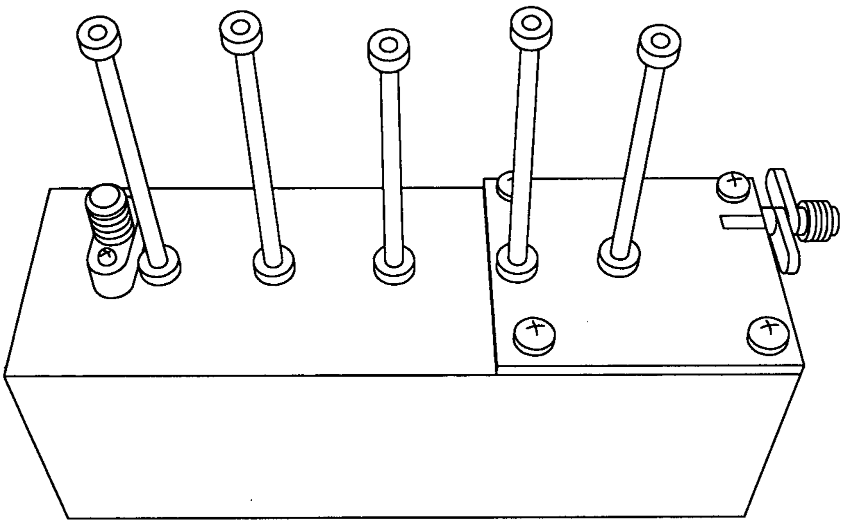

Fig. 9

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 16 30 5491

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	US 2010/045406 A1 (ANDREASSON KRISTER [SE]) 25 February 2010 (2010-02-25) * paragraph [0019] - paragraph [0020]; figure 1 * * paragraph [0037] - paragraph [0041]; figure 6 * * paragraph [0024] *	1-15	INV. H01P1/205
X	US 2008/024249 A1 (SCHREIBVOGEL GERHARD [AT]) 31 January 2008 (2008-01-31) * paragraph [0019] - paragraph [0020]; figure 2 *	1-15	
X	EP 2 800 201 A1 (HUAWEI TECH CO LTD [CN]) 5 November 2014 (2014-11-05) * paragraph [0024] - paragraph [0026]; figure 4 *	1-15	
A	US 4 278 957 A (STARAI TERRENCE M ET AL) 14 July 1981 (1981-07-14) * column 2, line 48 - column 3, line 23 *	1-15	
			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	27 October 2016	La Casta Muñoa, S

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 30 5491

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