(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 711 113 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
17.01.2024 Bulletin 2024/03

(21) Application number: **18819389.0**

(22) Date of filing: **16.11.2018**

(51) International Patent Classification (IPC):
H01P 1/205 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01P 1/2053

(86) International application number:
PCT/IT2018/050222

(87) International publication number:
WO 2019/097559 (23.05.2019 Gazette 2019/21)

(54) TUNABLE BANDPASS FILTER

ABSTIMMBARER BANDPASSFILTER

FILTRE PASSE-BANDE ACCORDABLE

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **16.11.2017 IT 201700131316**

(43) Date of publication of application:
23.09.2020 Bulletin 2020/39

(73) Proprietor: **RF Microtech S.r.l.**
06132 Perugia (IT)

(72) Inventors:
- **PELLICCIA, Luca**
  06034 Foligno (IT)
- **SORRENTINO, Roberto**
  06124 Perugia (IT)
- **CACCIAMANI, Fabrizio**
  06132 Perugia (IT)
- **TIRADOSSI, Davide**
  06084 Bettona (IT)

(74) Representative: **Petraz, Gilberto Luigi et al**
GLP S.r.l.
Viale Europa Unita, 171
33100 Udine (IT)

(56) References cited:
EP-A1- 2 814 112
EP-A1- 2 833 473
US-A- 5 157 363
US-A1- 2005 040 916
US-A1- 2015 280 298
US-B1- 6 198 363

Description

FIELD OF THE INVENTION

[0001] The present invention concerns a tunable band-pass filter also referred to as a tunable filter with metal cylinders or "tunable band-pass filter based on metal post technology" and a method to tune the pass band of a band-pass filter.

[0002] In particular, the band-pass filter according to the present invention can be the radiofrequency or microwave type, which allows to reconfigure its electrical response in frequency thanks to a mechanism for tuning the resonance frequency of the resonant cavities which make up the filter.

BACKGROUND OF THE INVENTION

[0003] Filters used in microwave and radiofrequency systems are known, to allow the passage of a generally narrow portion of the spectrum of frequencies and which enable the other frequencies to be suitably attenuated, sometimes at discretion until the unwanted frequencies are eliminated.

[0004] As is known, at present band-pass filters with metal cylinders made in cavities, or metal waveguides, are used in radiofrequency transmission/reception systems for applications in which fundamental requirements are: low insertion losses in the electrical response, reduced bulk compared to other technologies, and high operating power.

[0005] Generally, a known band-pass filter with metal cylinders is used for operating frequencies lower than 10-15GHz. At these operating frequencies, the use of other types of filters, having low losses, such as rectangular or circular guide filters, would entail significant bulk.

[0006] Generally, a known band-pass filter with metal cylinders comprises a plurality of resonant units or resonators disposed one after the other and connected to each other.

[0007] Each resonant unit is provided with a resonant cavity and, at least, a first aperture and a second aperture, respectively an input aperture and an output aperture of the electromagnetic field.

[0008] In this case, the output aperture of one of the resonant units is directly connected to the input aperture of the next resonant unit through a guide channel, also called an iris diaphragm.

[0009] Each resonant cavity is defined by metal surfaces and comprises a protruding element with metal surfaces, also referred to in the specific field as metal cylinder or "metal post", which protrudes from one of the surfaces defining the resonant cavity toward the inside of the latter.

[0010] The resonant units, usually more than two, are made in a single body or by connecting two or more components, together defining the band-pass filter.

[0011] The number "N" of resonant units of a filter defines the so-called order of the filter: a filter with "N" resonant units is an "N" order filter.

[0012] The particular conformation of the filter, that is, the sizes of the resonant cavities, the sizes of the iris diaphragms, the types of metal materials used, allow to define a predefined filtering band of the electromagnetic waves.

[0013] The above-described solutions of filters with cylinders, however, do not allow to adjust the tuning of the operating frequency of the pass band of the electrical response of the filter.

[0014] For this purpose, a solution is also known, in which a screw is associated with each protruding element located in the resonant cavity, that is, with the cylinder.

[0015] In particular, the screw is screwed into a through hole made in the protruding element, and the extent by which the screw is screwed determines how far the end protrudes into the resonant cavity. The length of the protruding part of the screw allows to define the entity of the adjustment of the pass band of the filter.

[0016] This solution, however, is not very efficient due to the high insertion losses that occur between the protruding element and the screw. The insertion losses can cause an excessive degradation of the signal of the pass band and undesirably modify the amplitude of the latter.

[0017] Moreover, this known solution is difficult to implement with automatic control mechanisms and in general is complex and expensive.

[0018] Another solution of a filter with cylinders is described in document US-A-2005/0040916, in which the filter comprises a plurality of resonant cavities connected to each other by corresponding iris diaphragms. In each resonant cavity a protruding element is installed, and facing each protruding element an adjustment screw is provided, screwed into a wall that defines the resonant cavity. By screwing or unscrewing the adjustment screw with respect to the wall, it is possible to move the adjustment screw closer to or away from the protruding element, thus obtaining the adjustment of the pass band of the filter.

[0019] Document US-A-2015/0280298 A1 describes another adjustable band-pass filter of the type with cylinders, substantially similar to that described in US-A-2005/0040916 A1, in which instead of providing adjustment screws which can be selectively screwed/unscrewed, perturbator elements are provided in the form of plate-like elements, selectively rotatable around an axis and each positioned in correspondence with a respective protruding element.

[0020] In both solutions described in US-A-2015/0280298 and US-A-2005/0040916 it is provided that the iris diaphragms, or portions of guide channels which connect and allow the electromagnetic coupling of two adjacent resonant cavities, are made passing through the separation wall of the latter.

[0021] More specifically, in US-A-2015/0280298 it is provided that the connecting iris diaphragm between pairs of resonant cavities extends over the entire height of the latter, that is, from the bottom wall, in which the protruding elements are attached, to the upper wall, which normally closes the resonant cavity.

[0022] In US-A-2005/0040916 the iris diaphragms are made starting from the upper wall of the resonant cavities and extend toward the bottom wall, but remaining at a predefined distance from the bottom wall where the protruding elements are attached.

[0023] Both these solutions, due to the particular conformation of the iris diaphragms, as well as their positioning with respect to the resonant cavities and the protruding elements positioned in the latter, do not allow to achieve sufficiently stable frequency response performances due to the significant sensitivity of the coupling values between cavities in these configurations.

[0024] EP-A-2814112 A1 discloses a resonator assembly comprising a first resonance and a second resonance post located in a same cavity, both operable to filter a signal at respective frequencies, and a signal coupling configured to couple the signal to a resonator output. The resonator makes it possible to provide an adaptable single device which implements more than one independent resonance within the same cavity volume, allowing to build significantly smaller cavity filters and which avoids the need to provide separate devices.

[0025] US-B-6198363 B1 describes a filter and frequency tuning element comprising a plurality of cavities separated by walls, and wherein the walls that separate two cavities are provided with coupling holes, to provide a better coupling of the cavities.

[0026] EP-A-2833473 A1 discloses a tunable filter comprising a plurality of resonance cavities, where a resonance tube and a tuning bolt are disposed in each resonance cavity, and the tuning blot penetrates into a space enclosed by the resonance tube. A tuning part is also disposed between the tuning bolt and the resonance tube. A driving unit is also disclosed that may drive an adjusting structure used for rotating the tuning part.

[0027] Such devices do not provide any solution to the problem of stability of the frequency response performances.

[0028] A solution is also known in which at least some of the lateral walls of each resonant cavity are mobile to vary the sizes of the resonant cavity. However, this solution too is not very efficient and has high insertion losses.

[0029] Moreover, this solution does not allow to obtain localized and/or different reconfigurations for the different resonant units defining the band-pass filter.

[0030] Furthermore, the known devices above do not allow to obtain a finer tuning of the frequency in response. One purpose of the present invention is therefore to provide a tunable band-pass filter which performs better than known tunable guide filters.

[0031] Another purpose of the invention is to provide a tunable band-pass filter which is efficient in allowing to reduce insertion or attenuation losses in the pass band, compared with known solutions.

[0032] Another purpose of the invention is to provide a tunable band-pass filter which allows to increase the operating power with low losses and reduced bulk compared to other technologies, such as guide filters.

[0033] Another purpose of the invention is to provide a tunable band-pass filter in which the form of the response of the filter does not deform with tuning.

[0034] Another purpose of the invention is to provide a tunable band-pass filter which allows to correct possible manufacturing errors which can negatively influence the form of the electrical response of the filter, adjusting independently and with small deviations the different resonators with mobile elements that are independent from each other.

[0035] Another purpose of the invention is to provide a tunable band-pass filter which is simple and economical to make.

[0036] The Applicant has devised, tested and embodied the present invention to overcome the shortcomings of the state of the art and to obtain these and other purposes and advantages.

SUMMARY OF THE INVENTION

[0037] The present invention is set forth and characterized in the independent claims, while the dependent claims describe other characteristics of the invention or variants to the main inventive idea.

[0038] The solution of the tunable band-pass filter according to the present invention allows to increase performances and achieve a finer tuning of the frequency in response with respect to known solutions thanks to the presence of the mobile perturbator elements associated with each protruding element. The present invention does not require the presence of electric circuits or electric control lines or polarization inside the filter itself.

[0039] Moreover, the presence of the mobile perturbator element, of the mechanical type, allows to contain production costs, improve reliability and resistance to mechanical stress

[0040] The present invention also concerns a method to tune the pass band of a band-pass filter.

[0041] The modification of the pass band determines a variation in the frequency of the electromagnetic field and the band width of the electromagnetic field.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] These and other characteristics of the present invention will become apparent from the following description of some embodiments, given as a non-restrictive example with reference to the attached drawings wherein:

- fig. 1 is a schematic view of a cross section of a tunable band-pass filter in accordance with an example useful for understanding the present invention;
- fig. 2 is an exploded schematic view of the section

of the band-pass filter in fig. 1;

- fig. 3 is a schematic view in section of a component of the tunable band-pass filter according to an example useful for understanding the present invention;
- fig. 4 is a schematic view of a first variant of fig. 3;
- fig. 5 is a schematic view of a second variant of fig. 3, forming part of the claimed invention;
- fig. 6 is a schematic view of a third variant of fig. 3;
- fig. 7 is an exploded schematic view of the band-pass filter in accordance with another embodiment which is not part of the invention;
- fig. 8 shows a possible variant embodiment of fig. 1, which is not part of the invention:

To facilitate comprehension, the same reference numbers have been used, where possible, to identify identical common elements in the drawings. It is understood that elements and characteristics of one embodiment can conveniently be incorporated into other embodiments without further clarifications.

DETAILED DESCRIPTION OF SOME EMBODIMENTS

[0043] The present invention concerns a band-pass filter indicated in its entirety by the reference number 10.

[0044] The filter 10 according to the present invention can be configured to adjust the operating frequency of its pass band in the case of applications having operating frequency usually lower than 15GHz, for example comprised between 2GHz and 8GHz.

[0045] The filter 10 comprises a plurality of resonant units 11 disposed one after the other and connected to each other so as to define together a guide channel 12, which extends between an input end 13 from which the electromagnetic field can penetrate and an output end 14 in which the electromagnetic field exits after being filtered.

[0046] In particular, the resonant units 11 can be reciprocally connected to each other to define a guide channel 12 which extends along a transmission path P of the electromagnetic signal indicated in figs. 1, 2 and 7 with a broken line.

[0047] According to a possible solution (figs. 1 and 2) the guide channel 12 can define a rectilinear transmission path P. This solution makes the filter 10 particularly easy to make and to adjust.

[0048] According to a variant embodiment (fig. 7), the transmission path P can be defined by consecutive non-collinear segments, that is, to define a broken line.

[0049] This solution allows to obtain a tunable filter 10 which can be adapted to the specific constructional and installation requirements required, for example, by dimensional constraints of the specific application.

[0050] At the input end 13 and at the output end 14, an input device 15 and an output device 16 of the electromagnetic field are respectively connected.

[0051] The input device 15 and the output device 16 of the electromagnetic field can comprise at least one electrical connector 17 (figs. 1 and 2).

[0052] According to an alternative (fig. 7), the input device 15 and the output device 16 comprise a waveguide 18 (fig. 7), in this specific case a rectangular guide for the introduction and exit of the electromagnetic field.

[0053] The input device 15 is connected to a first of the resonant units 11, and the output device 16 is connected to a second of the resonant units 11. The first and second resonant unit 11 can be located respectively at the input end and the output end of the transmission path P.

[0054] Examples of resonant units 11 are shown schematically in figs. 3-6, and can be reciprocally combined to define the tunable band-pass filter 10 according to the present invention.

[0055] Each resonant unit 11 is provided with a resonant cavity 19, and the resonant cavities 19, in turn, are connected to each other to define the guide channel 12.

[0056] The resonant cavities 19 can have substantially all the same shape and size.

[0057] According to variant embodiments, the resonant cavities 19 can have different shape and/or sizes. This solution allows to have greater degrees of freedom in the design of the filter 10.

[0058] According to a possible solution (figs. 2-7), the resonant cavities 19 can have a cylindrical conformation.

[0059] According to a variant embodiment, the resonant cavities 19 can have a prismatic conformation.

[0060] In accordance with other embodiments, not shown in the drawings, the resonant cavities 19 have an ellipsoidal conformation.

[0061] The resonant cavities 19 can be provided with at least one input aperture 20 and an output aperture 21 of the electromagnetic field.

[0062] In particular, it can be provided that the resonant cavities 19, of adjacent resonant units 11, are connected by respective channel portions 22, also called iris diaphragms. The channel portions 22 connect the output aperture 21 of a first of the resonant units 11 with the input aperture 20 of a second of the resonant units 11, adjacent and consecutive to the first resonant unit 11.

[0063] The sizes of the input apertures 20 and of the output apertures 21 of the resonant cavities 19 define the pass band amplitude and the level of adaptation of the electromagnetic signal that the filter 10 is able to have in its electrical response. In particular, the greater the sizes of the input apertures 20 and the output apertures 21, the greater the band amplitude of the electrical response of the filter 10.

[0064] The resonant cavities 19 are defined by one or more surfaces made of and/or coated with a metal material. The use of a metal material allows to contain and guide the electromagnetic field along the guide channel 12.

[0065] According to a possible solution, the whole resonant unit 11 can be made of a metal material, so that also the surfaces defining the resonant cavity 19 are metal.

[0066] By way of example only, the resonant units 11 are made of a material chosen from a group comprising steel, copper or aluminum.

[0067] According to a variant embodiment, the resonant unit 11 can be made of a dielectric material, for example a plastic material, and in which all the surfaces defining the resonant cavity 19 are coated with the metal material. The metal material can be chosen from a group comprising copper, silver, gold, or suchlike.

[0068] The coating of the resonant cavity 19 can be carried out by vapor deposition techniques, for example sputtering techniques, or Chemical or Physical Vapor Deposition.

[0069] According to a possible solution, the resonant cavities 19 can be defined by at least one base surface 23 and an upper surface 24, opposite the base surface 23.

[0070] According to a possible solution, the input apertures 20 and the output apertures 21, or also the channel portions 22 interposed between them, are positioned at the height of the base surface 23. This positioning allows to increase the stability of the frequency response of the filter during tuning, in practice obtaining a coupling of stable adjacent cavities as the operating frequency varies, thanks to the particular position of the input and output apertures which are located in a zone where the electromagnetic field is not very sensitive to alterations in the field that occur during the tuning of the operating frequency.

[0071] In accordance with this embodiment of the present invention, the base surfaces 23 of all the resonant units 11 are located on the same lying plane, and are connected to each other with surfaces defining said input apertures 20 and output apertures 21.

[0072] In accordance with another solution, the channel portions 22 extend from, that is, start from, the base surfaces 23, and are distanced from the upper surfaces 24 defining the resonant cavities 19, that is, they do not reach the upper surfaces 24. In other words, the channel portions 22 have a height lower than the height of the resonant cavities 19, and the height is determined in a direction incident to the base surface 23. This solution too allows to further increase the stability of the frequency response of the filter.

[0073] In accordance with the embodiments shown in figs. 1 and 2, the electric connectors 17 of the input 15 and output devices 16 are connected in proximity to the base surfaces 23 of the resonant cavities 19.

[0074] The positioning of the connection of the electric connectors 17 in the resonant cavities 19 allows to define also the functioning parameters of the filter 10, that is, its pass band.

[0075] According to one aspect of the present invention, each resonant cavity 19 is provided with a protruding element 25 which has at least its surfaces located in the resonant cavity 19 made of metal. The protruding element 25 is also referred to, in the specific field, as metal cylinder or "metal post", and protrudes from one of the surfaces defining the resonant cavity 19 and toward the inside thereof.

[0076] In particular, each protruding element 25 has an extension axis which intersects the transmission path P.

[0077] In possible solutions of the present invention, the protruding element 25 has a height H1 which is greater than the height H2 of the channel portion 22. The heights H1 and H2 are determined in a direction that is incident, preferably orthogonal, to the base surface 23. This allows to increase the stability of the frequency response of the filter during tuning, in practice obtaining couplings of stable adjacent cavities as the operating frequency varies.

[0078] The protruding element 25 defines an internal resonator of the resonant cavity 19.

[0079] In accordance with a possible solution, the protruding element 25 can be made in a single body with the resonant unit 11. This solution allows to contain the insertion losses to which the filter is subjected during use, since interruptions to the current lines that occur in the resonant cavity 19 are minimized.

[0080] According to a variant embodiment, the protruding element 25 can be made as a separate component and subsequently connected to the resonant unit 11, for example with mechanical connections, or glues, or welding. This allows to considerably simplify the operations of making the filter 10, consequently reducing the costs thereof.

[0081] The protruding element 25 can be made of an electrically conductive material or, according to a variant, at least the peripheral surfaces located in the resonant cavity 19 are coated with an electrically conductive material, that is, a metal.

[0082] According to a possible solution, the protruding element 25 is located protruding from the base surface 23 of the resonant cavity 19, in a direction incident to the base surface 23.

[0083] The protruding member 25 is provided with an end surface 26 which faces the upper surface 24 of the resonant cavity 19.

[0084] The reciprocal distance between the end surface 26 of the protruding element 25 and the upper surface 24 conditions the frequency response of the filter 10, according to the present invention.

[0085] In particular, from the electrical point of view, it can be assumed that the end surface 26 and the upper surface 24 define a structure similar to the plates of an electric capacitor, considerably influencing the resonance frequency of the protruding element 25 and consequently the operating frequency of the filter.

[0086] According to a possible solution, the protruding element 25 can have a cylindrical shape (figs. 2 and 3) or prismatic.

[0087] According to an alternative embodiment, the protruding element 25 can have a cross-section of variable size and/or shape along the axis of development of the protruding element 25.

[0088] According to a possible solution (fig. 4), the protruding element 25 can be defined by a base portion 27 connected to one of the surfaces defining the resonant cavity 19, in this specific case connected to the base surface 23, and by an end portion 28 connected to the base portion 27 and defining the terminal end of the resonant cavity 19 which is positioned in the resonant cavity 19.

[0089] According to a possible solution, the end portion 28 can have cross-section sizes, that is, transverse to the axis according to which the protruding element 25 protrudes, greater than the base portion 27.

[0090] This solution allows to increase the surface extension of the end surface 26 of the protruding element 25, and therefore, by increasing the electrical capacity at the end of the protruding element 25, it can further condition the operating frequency.

[0091] This solution allows to obtain a filter 10 which, given the same frequency response, has smaller sizes of the protruding element 25.

[0092] Moreover, this solution allows to increase the performance of the filter 10 by reducing the problems of response of the band-pass which generate perturbations due to the resonance modes of an order higher than the first.

[0093] According to one aspect of the present invention, at least one of the resonant units 11 of the filter 10 comprises a perturbator body 29 positioned in the resonant cavity 19, and a movement member 30 positioned outside the perturbator body 29 and configured to move the perturbator body 29 in the resonant cavity 19.

[0094] The function of the perturbator body 29 is to suitably perturb the electromagnetic field passing through the guide channel 12, without altering it excessively and compromising the resonance of the field itself and therefore the stability of the electrical response of the filter 10.

[0095] According to a possible embodiment of the invention, the perturbator body 29 is positioned in the space comprised between the protruding element 25 and the surfaces defining the resonant cavity 19.

[0096] In particular, it can be provided that the perturbator body 29 is installed in the interspace between the upper surface 24 of the resonant cavity 19 and the end surface 26 of the protruding element 25.

[0097] This positioning of the perturbator body 29 allows to modify the frequency response of the electromagnetic field, in relation to the different position assumed by the perturbator body 29.

[0098] According to a possible solution, the perturbator bodies 29 installed in the resonant cavities 19 have the same shape and size. This solution allows to obtain a modular and low cost structure.

[0099] According to a possible variant embodiment, the perturbator bodies 29 have different shape and/or sizes, or at least some of them have. The use of perturbator bodies 29 of different shapes allows, for example in applications in which it is not possible to use perturbation bodies all of the same shape and size, to obtain a correct tuning of the response of the filter.

[0100] According to a possible embodiment, the perturbator bodies 29 are installed in the resonant cavity 19 aligned along the transmission path P.

[0101] The perturbator bodies 29 can be made, or at least one part made, with a dielectric material.

[0102] The use of some dielectric materials, for example ceramic with high relative permittivity (>10), allows to perturb the electromagnetic field significantly, while at the same time containing insertion losses.

[0103] According to a variant embodiment, the perturbator bodies 29 can be made of a metal material. This solution allows to simplify the operations of making the perturbator bodies 29, making them particularly economical. Moreover, the use of metal material makes the perturbator bodies 29 particularly resistant and usable for greater tuning intervals, given the same sizes.

[0104] According to another variant embodiment, the perturbator bodies 29 can be made partly of a metal material and partly of a dielectric material. This solution facilitates the construction of the perturbator bodies 29.

[0105] According to possible solutions, the perturbator bodies 29 can be coated on the surface with a metal layer, for example with one or the other of the metallization techniques described above.

[0106] According to a possible variant embodiment, the perturbator bodies 29 can comprise a perturbator element 31 and at least one support shaft 32 configured to support the perturbator element 31 in the resonant cavity 19.

[0107] The perturbator element 31 can be plate-shaped.

[0108] According to possible variant embodiments, the perturbator element 31 can have any shape whatsoever, even irregular. By way of example only, it can be provided that the perturbator element 31 does not have a circular symmetry with respect to its axis of rotation.

[0109] In this way it is possible to allow a different perturbation of the electromagnetic field during the rotation of the perturbator bodies 29, that is, when they change relative position with respect to the maximum or minimum points of the electromagnetic field in the resonant cavity 19.

[0110] According to possible solutions, the perturbator element 31 has a symmetrical conformation with respect to at least one axis of symmetry and the support shaft 32 is configured to support the perturbator element 31 around the axis of symmetry.

[0111] According to a possible variant embodiment, the support shaft 32 is configured to support the perturbator element 31 on a non-symmetrical axis of the perturbator element 31.

[0112] The perturbator element 31 can have a rectangular shape and be supported by the support shaft 32 in correspondence with the center line of the perturbator element 31.

[0113] According to a possible solution, the support shaft 32 can be configured to support the perturbator element 31 on opposite sides of the latter.

[0114] According to a variant embodiment, not shown, the support shaft 32 is configured to support the perturbator element 31 with a free end thereof, that is, to support the perturbator element 31 in a cantilevered manner.

[0115] The support shafts 32 can be installed in the resonant units 11 with respective support elements, not shown. The support elements can be chosen from a group comprising at least one of either a bushing, a sleeve or a bearing.

[0116] According to possible solutions, the resonant units 11 can be provided with support seatings 33 configured to support and allow movement of the perturbator bodies 29.

[0117] In accordance with possible solutions, the support seatings 33 are installed on the support shafts 32.

[0118] According to one embodiment of the invention (figs. 1-5 and 7), the perturbator bodies 29 are selectively rotatable, as described hereafter, around respective axes X, located transverse to the transmission path P and, in this specific case, transverse to the protruding axis of the protruding element 25.

[0119] According to a variant embodiment (fig. 6), the perturbator bodies 29 can be movable linearly along an axis X.

[0120] In accordance with this embodiment, it can be provided that the perturbator bodies 29 can be moved linearly toward/away from the protruding element 25 in order to modify, in this way, the frequency response.

[0121] According to the claimed invention, the perturbator bodies 29 can be moved both linearly and made to rotate with respect to an axis X thereof, as indicated by the arrows shown in fig. 5.

[0122] The axes X of the perturbator bodies 29 can coincide with the axes of the support shafts 32.

[0123] The movement member 30 is the mechanical type and this prevents possible electromagnetic interference with the electromagnetic field that passes through the guide channel 12.

[0124] Moreover, the positioning of the movement member 30 outside the resonant cavity 19 allows to reduce electromechanical losses and therefore to increase the efficiency of the filter 10. Furthermore, this positioning facilitates the operations to adjust the tuning of the filter 10.

[0125] The movement member 30 can be chosen from a group comprising at least one of either a gear mechanism, a motor, a linear actuator, an articulated mechanism, an actuation lever or crank or a possible combination of the above.

[0126] According to a possible solution (figs. 1-5 and 7), the movement member 30 is configured to adjust at least the angular position of the perturbator body 29 with respect to the axis X.

[0127] By way of example only, it can be provided that the rotation needed to obtain the maximum perturbation effect of the resonance frequency can be even only 90°.

[0128] According to a possible solution, the movement member 30 (fig. 6) can be configured to move the perturbator body 29 linearly in the respective resonant cavity 19. By way of example only, it can be provided that the movement member 30 is configured to move the perturbator body 29 linearly and in a direction parallel to the axis X defined above, in order to modify its position in the resonant cavity 19, for example toward/away from the end surface 26.

[0129] In accordance with the claimed invention (fig. 5), the movement member 30 can be configured to move the at least one perturbator body 29 in a combined manner, both linear and rotary.

[0130] According to a possible solution of the present invention, all the resonant units 11 of the filter 10 are provided with their own perturbator body 29.

[0131] This solution allows to increase the number of adjustments that can be implemented in the filter 10.

[0132] According to the invention (figs. 1-6), each perturbator body 29 is connected to a respective and independent movement member 30. This solution allows to adjust the non-synchronized position of the perturbator bodies 29, for example if it is necessary to correct errors of manufacture (which can negatively influence the form of the electrical response of the filter), or if it is necessary to tune the different resonators independently and by small quantities with perturbator bodies that are independent of one another.

[0133] According to a variant embodiment (fig. 7) which is not part of the invention, the perturbator bodies 29 are all connected to a single movement member 30. This allows to obtain a synchronous adjustment of the position for all the perturbator bodies 29.

[0134] This solution allows to obtain a synchronous tuning, that is, of the same frequency value, of all the resonators of the filter. This allows to obtain a stable tuning of the response of the filter 10, preventing undesired variations in the response of the filter as the frequency changes.

[0135] The at least one movement member 30 can be connected to the perturbator body 29 in correspondence with the support shaft 32 thereof.

[0136] In this embodiment, it can be provided that at least part of the support shaft 32 extends through, in the support seating 33 made in the resonant unit 11, and has a free end located outside the latter and connected to the movement member 30.

[0137] In accordance with a possible embodiment which is not part of the invention, shown for example in figs. 7 and 8, it can be provided that at least two of the perturbator bodies 29 are reciprocally connected to one another, so that the movement of one determines the movement of the other as well.

[0138] By way of example only, it can be provided that the perturbator element 31 of a first perturbator body 29 and the perturbator element 31 of a second perturbator body 29 are installed on the same support shaft 32.

[0139] For example with reference to fig. 7, it can be provided that pairs of perturbator elements 31, each installed in a respective resonant cavity 19, are associated with the same support shaft 32 installed between the respective resonant units 11. Such variant is not part of the invention.

[0140] According to a variant embodiment, shown in fig. 8, if the resonant units 11 are aligned along a rectilinear transmission path P, it can be provided that the perturbator elements 31 of each of the resonant units 11 are all installed on a common support shaft 32. Such variant is not part of the invention.

[0141] The support shaft 32 can be installed passing through the resonant cavities 19 of the resonant units 11.

[0142] According to a possible solution (figs. 2 and 7), the filter 10 can comprise a base body 34 and at least one covering body 35 coupled with the base body 34 to define, together, the resonant units 11.

[0143] In particular, it can be provided that the base body 34 and the covering body 35 define, together, the resonant cavities 19 reciprocally connected to each other by the channel portions 22 of the guide channel 12.

[0144] By way of example only, the base body 34 and the covering body 35 can be made as separate components and reciprocally coupled together by means of connection elements, for example mechanical. According to a possible solution, the connection elements can be chosen from a group comprising threaded connection elements, plugs, pins, or suchlike.

[0145] With reference to the embodiment shown in fig. 2, the base body 34 can define the resonant cavities 19 and the guide channel 12 in which the protruding elements 25 are disposed. The covering body 35 is located to close the resonant cavities 19 at the top.

[0146] With reference to fig. 7, which shows an embodiment which is not part of the invention, the filter 10 comprises an intermediate body 36 interposed between the covering body 35 and the base body 34 and in which the perturbator bodies 29 are positioned.

[0147] The intermediate body 36 is provided with a plurality of through apertures defining, in use, part of the resonant cavities 19 of the resonant units 11.

[0148] The intermediate body 36 and the covering body 35 can be provided with grooves, made in coordinated positions, and defining, when coupled together, the support seatings 33 for the support shaft 32.

[0149] It is clear that modifications and/or additions of parts can be made to the band-pass filter 10 described heretofore without departing from the field and scope of the present invention.

Claims

1. Tunable band-pass filter comprising a plurality of resonant units (11) each provided with a resonant cavity (19) in which a protruding element (25) is located that protrudes from a base surface (23) of said resonant cavity (19) and toward the inside of the latter, said resonant cavities (19) being connected with each other to define a guide channel (12) for the passage of an electromagnetic field, wherein at least one of said resonant units (11) comprises a perturbator body (29) positioned in the respective resonant cavity (19), and a movement member (30) positioned outside said resonant cavity (19) and configured to move said perturbator body (29) in said resonant cavity (19);

   wherein said resonant cavities (19) of said resonant units (11) are connected to each other by respective channel portions (22), and said channel portions (22) are positioned at the height of the base surface (23);
   wherein said at least one movement member (30) is configured to adjust at least the angular position of said at least one perturbator body (29) and to move said at least one perturbator body (29) linearly in the respective resonant cavity (19), and wherein each perturbator body (29) is connected to a respective and independent movement member (30).

2. Filter as in claim 1, **characterized in that** said resonant cavities (19) are defined by said base surface (23) and by an upper surface (24), opposite the base surface (23), **and in that** said channel portions (22) extend from said base surfaces (23) and are distanced from said upper surfaces (24).

3. Filter as in claim 1 or 2, **characterized in that** said protruding elements (25) have a height (H1) that is bigger than the height (H2) of said channel portion (22), said heights (H1, H2) being determined in a direction perpendicular to the base surface (23).

4. Filter as in any claim hereinbefore, **characterized in that** said base surfaces (23) of all the resonant units (11) are located on a same lying plane.

5. Filter as in any claim hereinbefore, **characterized in that** said resonant cavities (19) are defined by a base surface (23) from which said protruding elements (25) are located protruding and by an upper surface (24) opposing the base surface (23), **in that** said protruding elements (25) each comprise an end surface (26) facing said upper surface (24), **and in that** said perturbator bodies 29 are installed in the interspace present between the upper surface (24) and said end surface (26).

6. Filter as in any claim hereinbefore, **characterized in that** said perturbator bodies (29) comprise a perturbator element (31) and at least a support shaft (32) configured to support the perturbator element (31) in said resonant cavity (19).

7. Method to tune the pass band of a band-pass filter

that provides to make an electromagnetic field pass through a guide channel (12) defined by a plurality of resonant cavities (19) of respective resonant units (11), connected with each other, each cavity comprising a protruding element (25) that protrudes from one of the surfaces defining said resonant cavity (19) being located in said resonant cavities (19), said resonant cavities (19) of said resonant units (11) being connected to each other by respective channel portions (22) that are positioned at the height of the base surface (23), wherein said movement members (30) are configured to adjust at least the angular position of said perturbator bodies (29) and to move said perturbator bodies (29) linearly in the respective resonant cavities (19), and wherein each perturbator body (29) is connected to a respective and independent movement member (30), the method further comprising moving said perturbator body (29) in at least one of said resonant cavities (19), by means of a movement member (30) positioned outside said resonant cavity (19), in order to modify the pass band of the band-pass filter by means of a perturbation of the electromagnetic field located inside said guide channel (12).

Patentansprüche

1. Abstimmbares Bandpassfilter, aufweisend eine Mehrzahl von Resonanzeinheiten (11), die jeweils mit einem Resonanzhohlraum (19) versehen sind, in dem sich ein vorstehendes Element (25) befindet, das von einer Grundfläche (23) des Resonanzhohlraums (19) und in Richtung des Inneren des letzteren vorsteht, wobei die Resonanzhohlräume (19) miteinander verbunden sind, um einen Führungskanal (12) für den Durchgang eines elektromagnetischen Feldes zu definieren, wobei mindestens eine der Resonanzeinheiten (11) einen Störkörper (29), der in dem entsprechenden Resonanzhohlraum (19) positioniert ist, und ein Bewegungselement (30) aufweist, das außerhalb des Resonanzhohlraums (19) positioniert ist und konfiguriert ist, um den Störkörper (29) in dem Resonanzhohlraum (19) zu bewegen; wobei die Resonanzhohlräume (19) der Resonanzeinheiten (11) durch entsprechende Kanalabschnitte (22) miteinander verbunden sind und die Kanalabschnitte (22) auf der Höhe der Grundfläche (23) angeordnet sind;
wobei das mindestens eine Bewegungselement (30) konfiguriert ist, zumindest die Winkelposition des mindestens einen Störkörpers (29) einzustellen und den mindestens einen Störkörper (29) linear in dem entsprechenden Resonanzhohlraum (19) zu bewegen, und wobei jeder Störkörper (29) mit einem entsprechenden und unabhängigen Bewegungselement (30) verbunden ist.

2. Filter nach Anspruch 1, **dadurch gekennzeichnet, dass** die Resonanzhohlräume (19) durch die Grundfläche (23) und durch eine der Grundfläche (23) gegenüberliegende obere Fläche (24) definiert sind, **und dadurch, dass** sich die Kanalabschnitte (22) von den Grundflächen (23) aus erstrecken und von den oberen Flächen (24) beabstandet sind.

3. Filter nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** die vorstehenden Elemente (25) eine Höhe (H1) haben, die größer ist als die Höhe (H2) des Kanalabschnitts (22), wobei die Höhen (H1, H2) in einer Richtung senkrecht zur Grundfläche (23) bestimmt werden.

4. Filter nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** sich die Grundflächen (23) aller Resonanzeinheiten (11) auf derselben liegenden Ebene befinden.

5. Filter nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Resonanzhohlräume (19) durch eine Grundfläche (23), von der aus die vorstehenden Elemente (25) vorstehend angeordnet sind, und durch eine der Grundfläche (23) gegenüberliegende obere Fläche (24) definiert sind, **dadurch, dass** die vorstehenden Elemente (25) jeweils eine der oberen Fläche (24) zugewandte Endfläche (26) aufweisen, **und dadurch, dass** die Störkörper (29) in dem Zwischenraum, der zwischen der oberen Fläche (24) und der Endfläche (26) vorhanden ist, installiert sind.

6. Filter nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Störkörper (29) ein Störelement (31) und mindestens einen Stützschaft (32) aufweisen, der konfiguriert ist, um das Störelement (31) in dem Resonanzhohlraum (19) zu stützen.

7. Verfahren zum Abstimmen des Durchlassbandes eines Bandpassfilters, das dafür sorgt, dass ein elektromagnetisches Feld durch einen Führungskanal (12) läuft, der durch eine Mehrzahl von Resonanzhohlräumen (19) von entsprechenden Resonanzeinheiten (11) definiert ist, die miteinander verbunden sind, wobei jeder Hohlraum aufweist:
ein vorstehendes Element (25), das von einer der Flächen hervorsteht, die den Resonanzhohlraum (19) definieren, das in den Resonanzhohlräumen (19) angeordnet ist, wobei die Resonanzhohlräume (19) der Resonanzeinheiten (11) miteinander durch entsprechende Kanalabschnitte (22) verbunden sind, die auf der Höhe der Grundfläche (23) positioniert sind, wobei die Bewegungselemente (30) konfiguriert sind, zumindest die Winkelposition der Störkörper (29) einzustellen und die Störkörper (29) linear in den entsprechenden Resonanzhohlräumen

(19) zu bewegen, und wobei jeder Störkörper (29) mit einem entsprechenden und unabhängigen Bewegungselement (30) verbunden ist, wobei das Verfahren ferner aufweist: Bewegen des Störkörpers (29) in mindestens einem der Resonanzhohlräume (19) durch ein Bewegungselement (30), das außerhalb des Resonanzraumes (19) angeordnet ist, um das Durchlassband des Bandpassfilters durch eine Störung des elektromagnetischen Feldes, das sich im Inneren des Führungskanals (12) befindet, zu verändern.

Revendications

1. Filtre passe-bande accordable comprenant une pluralité d'unités résonantes (11) présentant chacune d'une cavité résonante (19) dans laquelle est situé un élément en saillie (25) qui fait saillie d'une surface de base (23) de ladite cavité résonante (19) et vers l'intérieur de cette dernière, lesdites cavités résonantes (19) étant reliées entre elles pour définir un canal de guidage (12) pour le passage d'un champ électromagnétique, au moins une desdites unités résonantes (11) comprenant un corps perturbateur (29) positionné dans la cavité résonante respective (19), et un élément de mouvement (30) positionné à l'extérieur de ladite cavité résonante (19) et configuré pour déplacer ledit corps perturbateur (29) dans ladite cavité résonante (19) ;

   lesdites cavités résonantes (19) desdites unités résonantes (11) étant reliées les unes aux autres par des parties de canal respectives (22), et lesdites parties de canal (22) étant positionnées à la hauteur de la surface de base (23) ;
   ledit au moins un élément de mouvement (30) étant configuré pour ajuster au moins la position angulaire dudit au moins un corps perturbateur (29) et pour déplacer ledit au moins un corps perturbateur (29) de façon linéaire dans la cavité résonante respective (19), et
   chaque corps perturbateur (29) étant relié à un organe de déplacement respectif et indépendant (30).

2. Filtre selon la revendication 1, **caractérisé en ce que** lesdites cavités résonantes (19) sont définies par ladite surface de base (23) et par une surface supérieure (24), opposée à la surface de base (23), et **en ce que** lesdites portions de canal (22) s'étendent depuis lesdites surfaces de base (23) et sont espacées desdites surfaces supérieures (24).

3. Filtre selon la revendication 1 ou la revendication 2, **caractérisé en ce que** lesdits éléments saillants (25) ont une hauteur (H1) supérieure à la hauteur (H2) de ladite partie de canal (22), lesdites hauteurs (H1, H2) étant déterminées dans une direction perpendiculaire à la surface de base (23).

4. Filtre selon l'une quelconque des revendications précédentes, **caractérisé en ce que** lesdites surfaces de base (23) de toutes les unités résonantes (11) sont situées sur un même plan d'extension.

5. Filtre selon l'une quelconque des revendications précédentes, **caractérisé en ce que** lesdites cavités résonantes (19) sont définies par une surface de base (23) à partir de laquelle lesdits éléments saillants (25) sont situés en saillie et par une surface supérieure (24) opposée à la surface de base (23), **en ce que** lesdits éléments saillants (25) comprennent chacun une surface d'extrémité (26) tournée vers ladite surface supérieure (24), et **en ce que** lesdits corps perturbateurs (29) sont installés dans l'espace intermédiaire présent entre la surface supérieure (24) et ladite surface d'extrémité (26).

6. Filtre selon l'une quelconque des revendications précédentes, **caractérisé en ce que** lesdits corps perturbateurs (29) comprennent un élément perturbateur (31) et au moins un arbre de support (32) configuré pour supporter l'élément perturbateur (31) dans ladite cavité résonante (19).

7. Procédé pour accorder la bande passante d'un filtre passe-bande qui permet de faire passer un champ électromagnétique à travers un canal de guidage (12) défini par une pluralité de cavités résonantes (19) d'unités résonantes respectives (11), reliées entre elles, chaque cavité comprenant un élément saillant (25) qui fait saillie depuis l'une des surfaces définissant ladite cavité résonante (19), en étant situé dans lesdites cavités résonantes (19), lesdites cavités résonantes (19) desdites unités résonantes (11) étant reliées les unes aux autres par des parties de canal respectives (22) qui sont positionnées à la hauteur de la surface de base (23), lesdits éléments de mouvement (30) étant configurés pour ajuster au moins la position angulaire desdits corps perturbateurs (29) et pour déplacer lesdits corps perturbateurs (29) de façon linéaire dans les cavités résonantes respectives (19), et chaque corps perturbateur (29) étant relié à un organe de déplacement (30) respectif et indépendant, le procédé comprenant en outre le fait de déplacer ledit corps perturbateur (29) dans au moins une desdites cavités résonantes (19), au moyen d'un organe de déplacement (30) positionné à l'extérieur de ladite cavité résonante (19), afin de modifier la bande passante du filtre passe-bande au moyen d'une perturbation du champ électromagnétique situé à l'intérieur dudit canal de guidage (12).

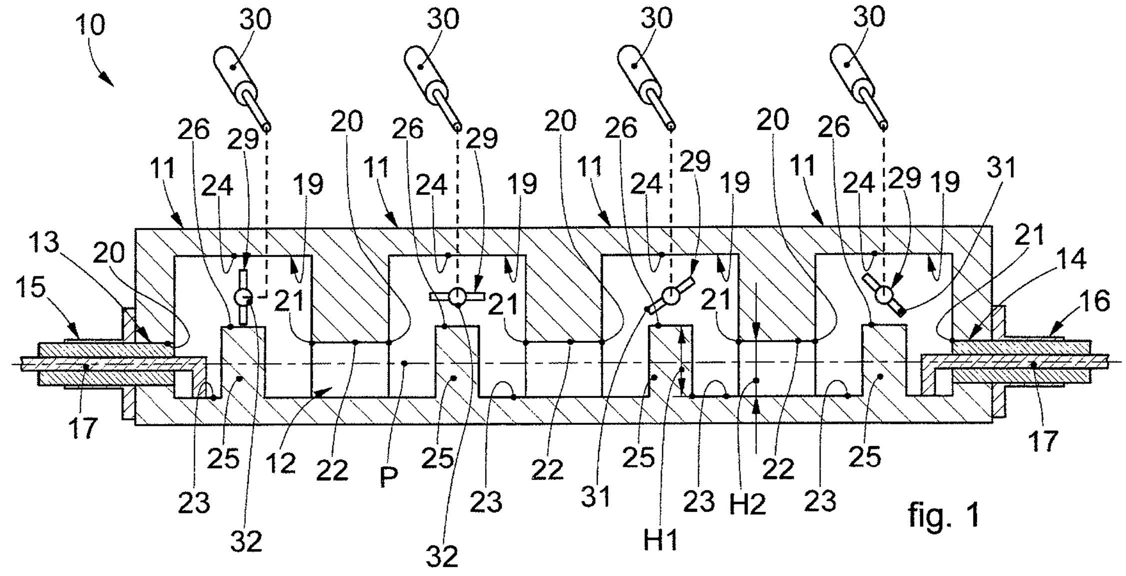
10
30
26
29
20
24
19
11
21
13
14
15
16
31
12
22
23
25
17
32
P
H1
H2

fig. 1

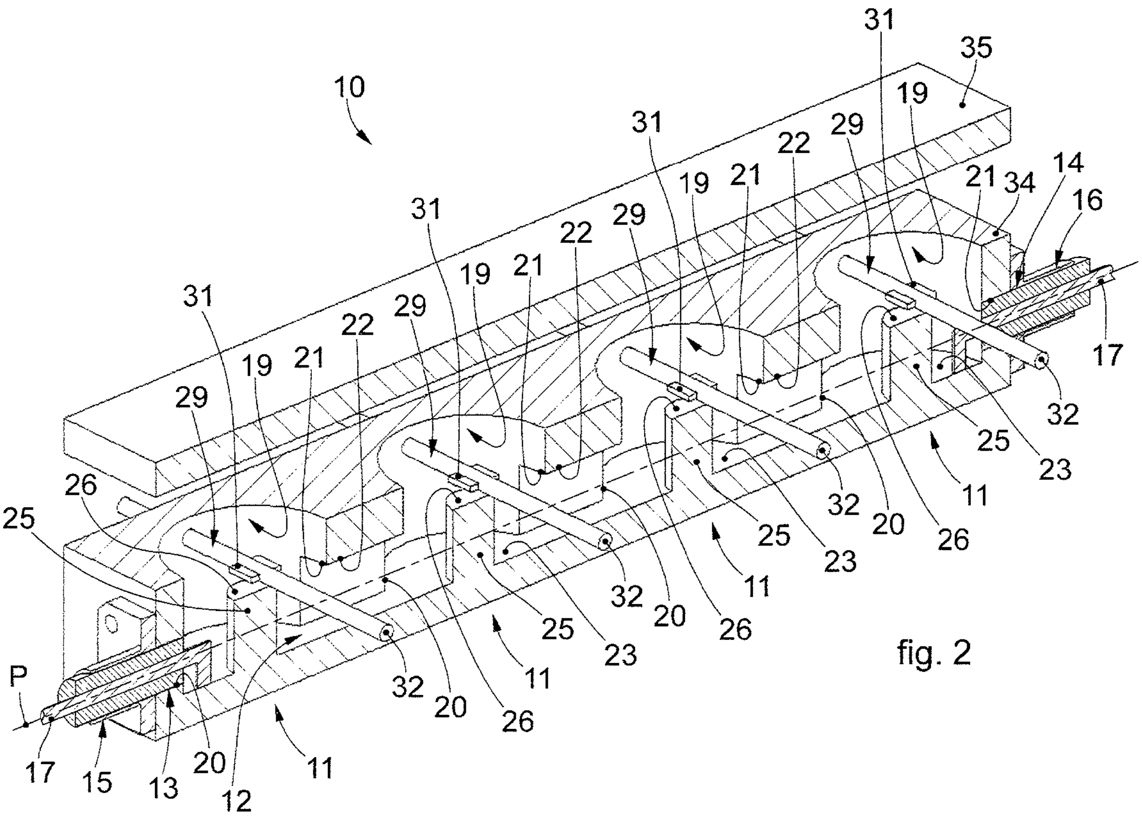
10
31
35
19
22
29
21
34
14
16
17
32
25
23
11
20
26
P
15
13
12

fig. 2

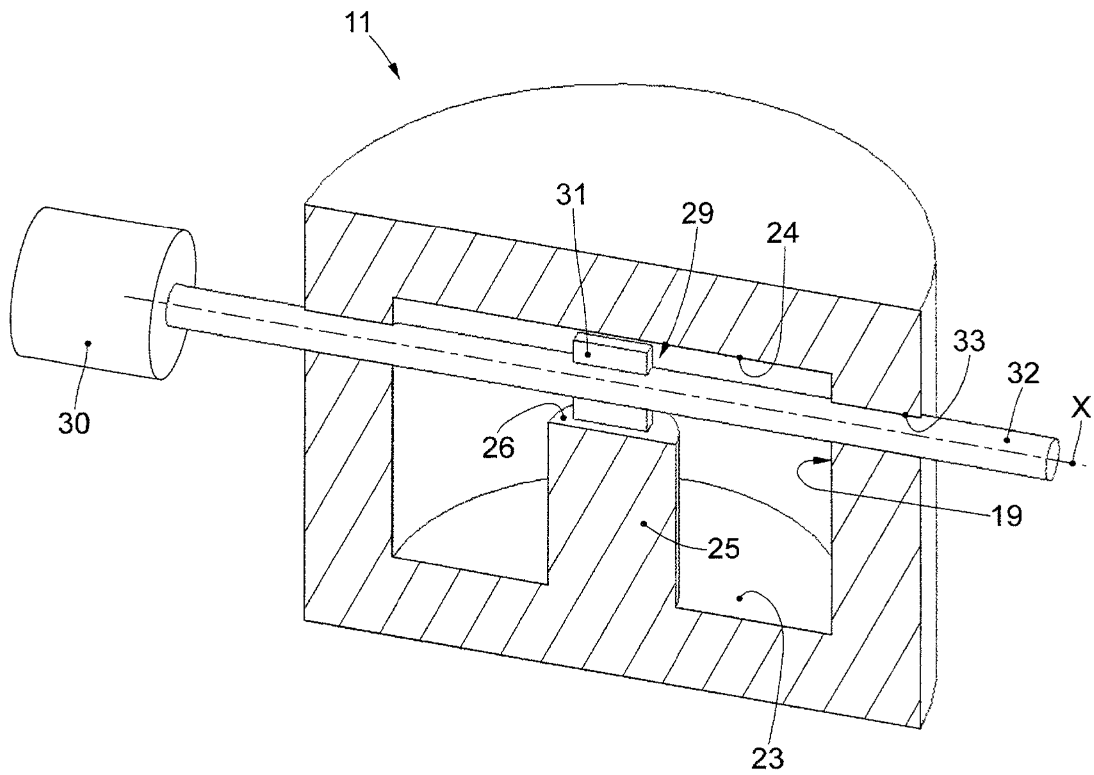

fig. 3

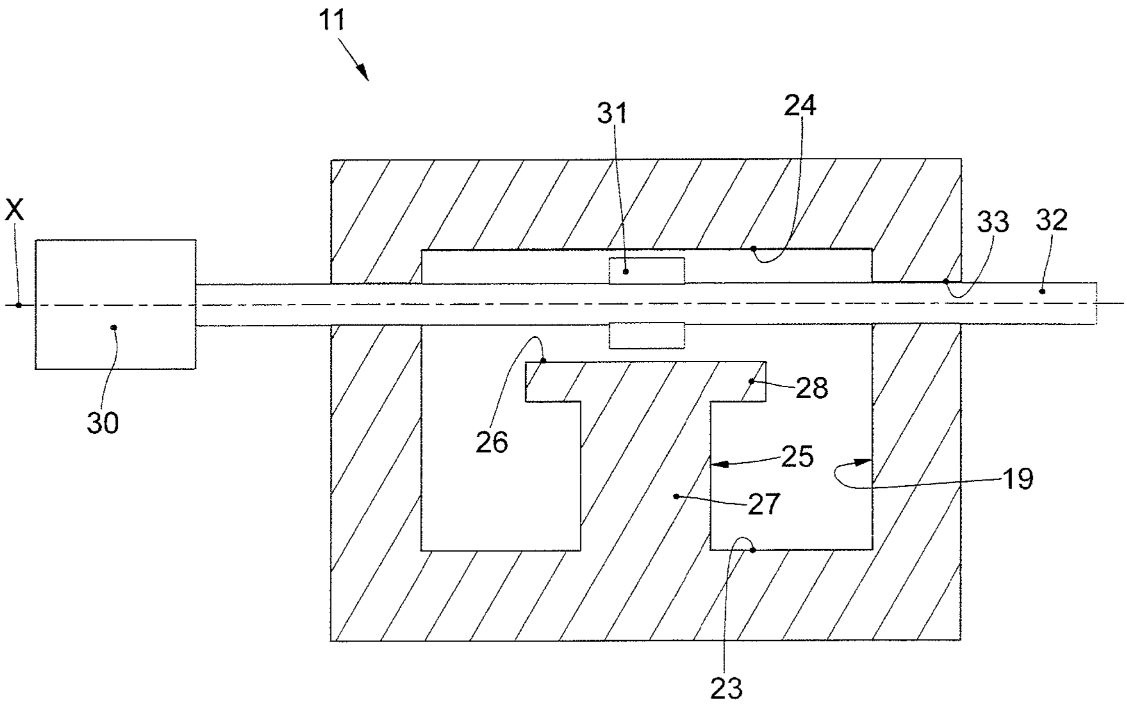

fig. 4

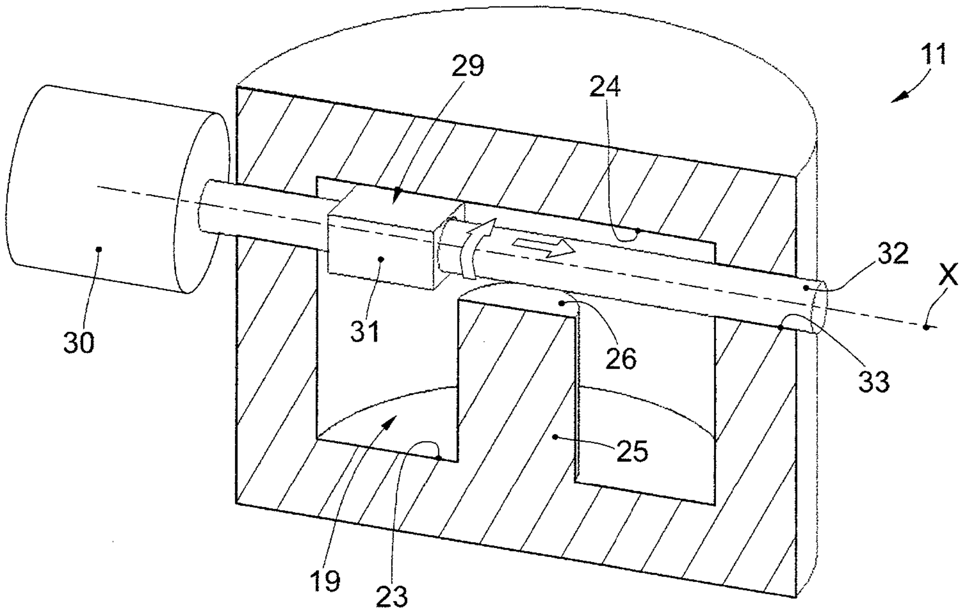

fig. 5

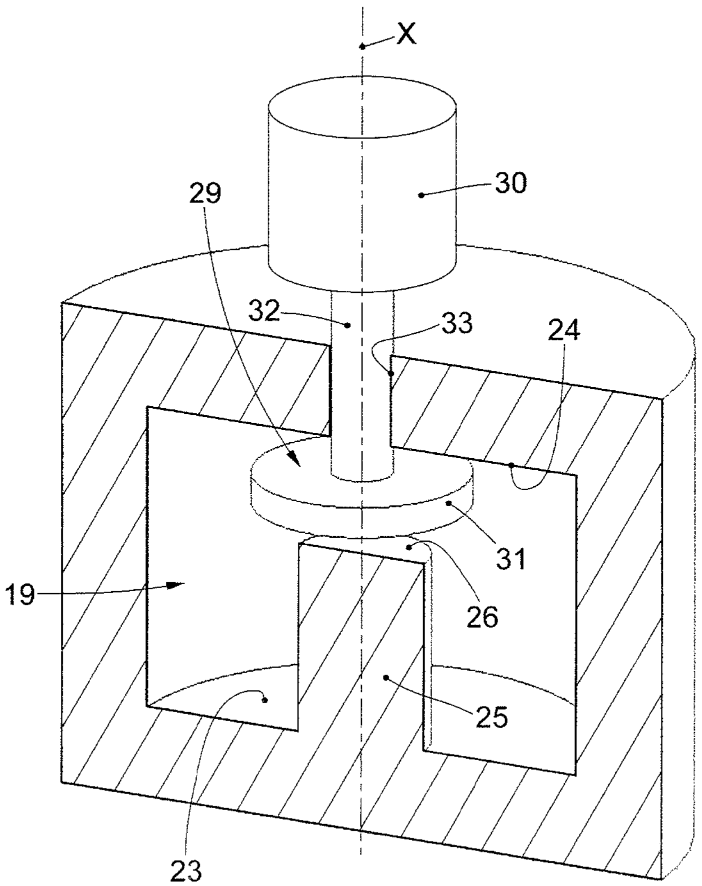

fig. 6

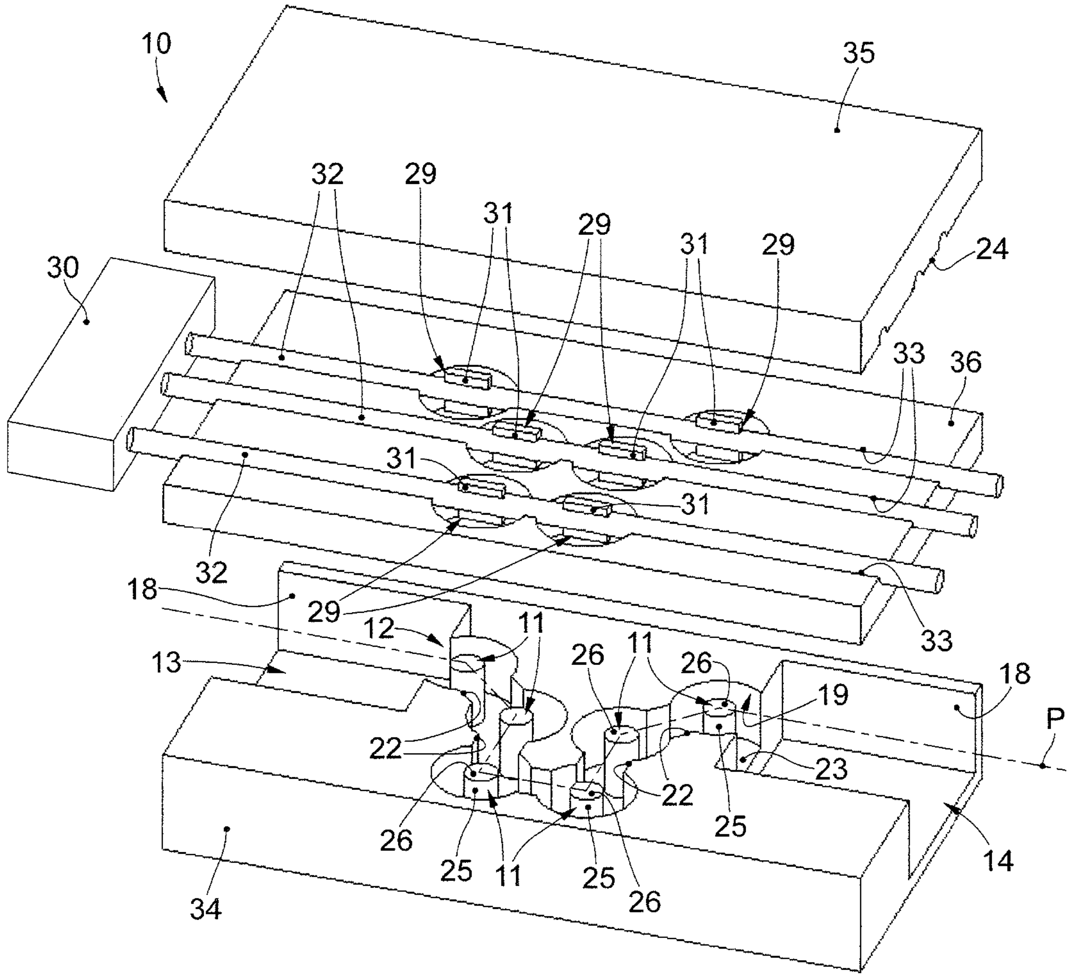
10
35
32
29
31
29
31
29
24
30
33
36
31
31
32
33
32
29
18
33
12
11
13
26
11
26
19
18
P
22
23
22
25
26
14
25
11
25
26
34

fig. 7

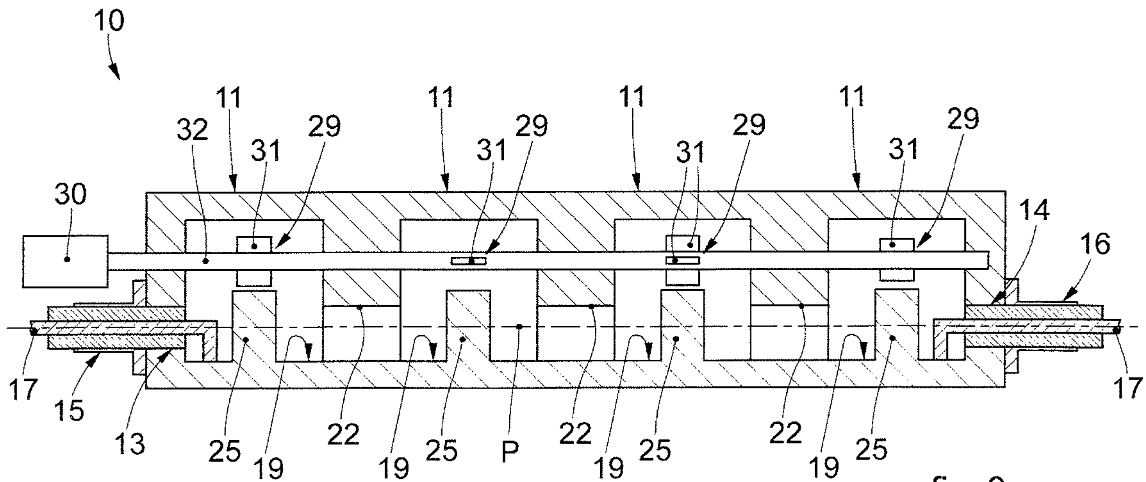
10
11
11
11
11
32
29
31
31
29
31
29
31
29
30
14
16
17
15
13
25
19
22
19
25
P
22
19
25
22
19
25
17

fig. 8

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20050040916 A **[0018] [0020] [0022]**
- US 20150280298 A1 **[0019]**
- US 20050040916 A1 **[0019]**
- US 20150280298 A **[0020] [0021]**
- EP 2814112 A1 **[0024]**
- US 6198363 B1 **[0025]**
- EP 2833473 A1 **[0026]**