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(54) Adjustable coupling

(57) The present invention relates to a microwave filter comprising at least one resonator having electrically conductive walls (2, 3) defining a resonator cavity (4) and a coupling mechanism (7, 7', 7") for coupling electromagnetic energy into or out of the resonator cavity (4). The coupling mechanism (7, 7', 7'') comprises a through bore (9, 9'') extending through a wall portion (2) of the resonator extending transversely to the wall portion (2), a coupling element (10, 10') extending through the through bore (9, 9") and comprising a first elongate portion (11b, 11b") adjacent the opening of the through bore (9, 9") into the resonator cavity (4) and a second elongate portion (11a, 25) adjacent the opposite opening of the through bore (9, 9"), wherein the first elongate portion (11b, 11b") projects at least partly into the resonator cavity (4), and wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are electrically conductive and arranged such that electromagnetic energy can be transferred between the first elongate portion (11b, 11b ") and the second elongate portion (11a, 25), a dielectric mounting (8) for securing the coupling element (10, 10') in the wall portion (2) such that the coupling element (10, 10') is electrically isolated from the wall portion (2), and an adjustment means (14) operable to selectively change the coupling characteristics of the coupling mechanism (7, 7', 7"). The adjustment means (14) is operable to displace the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) with respect to each other to thereby selectively advance the first elongate portion (11b, 11b") from the through bore (9, 9") into the resonator cavity (4) or retract the first elongate portion (11b, 11b") from the resonator cavity (4) into the through bore (9, 9").

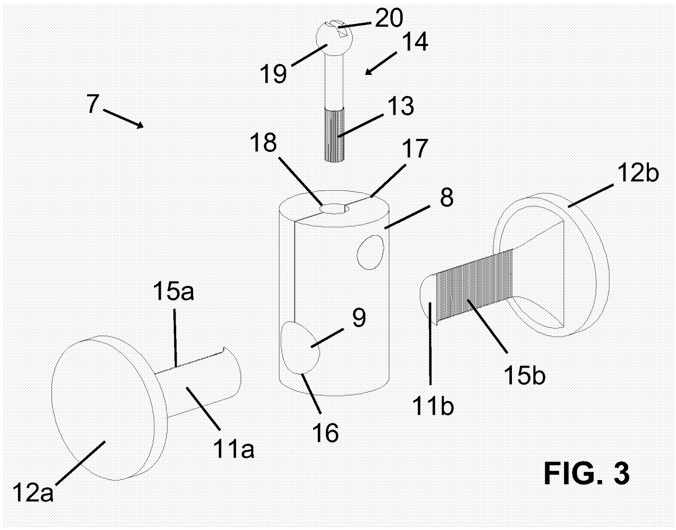

FIG. 3

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Description

[0001] The present invention relates to a microwave filter comprising at least one resonator having electrically conductive walls defining a resonator cavity and a coupling mechanism for coupling electromagnetic energy into or out of the resonator cavity, wherein the coupling mechanism comprises a through bore through a wall portion of the resonator extending transversely to the wall portion, an electrically conductive coupling element extending through the through bore and comprising a first elongate portion adjacent the opening of the through bore into the resonator cavity and a second elongate portion adjacent the opposite opening of the through bore, wherein the first elongate portion projects at least partly into the resonator cavity, a dielectric mounting for securing the coupling element in the through bore such that the coupling element is electrically isolated form the wall portion, and an adjustment means operable to selectively change the coupling characteristics of the coupling mechanism.

[0002] The microwave region of the electromagnetic spectrum finds widespread use in various fields of technology. Exemplary applications include wireless communication systems, such as mobile communication and satellite communication systems, as well as navigation and radar technology. The growing number of microwave applications increases the possibility of interference occurring within a system or between different systems. Therefore, the microwave region is divided into a plurality of distinct frequency bands. To ensure, that a particular device only communicates within the frequency band assigned to this device, microwave filters are utilized to perform band-pass and band reject functions during transmission and/or reception. Accordingly, the filters are used to separate the different frequency bands and to discriminate between wanted and unwanted signal frequencies so that the quality of the received and of the transmitted signals is largely governed by the characteristics of the filters. Commonly, the filters have to provide for a small bandwidth and a high filter quality.

[0003] Commonly, microwave filters include a plurality of resonators or resonant sections which are coupled together in various configurations. Each such resonator usually comprises a space contained within a closed or substantially closed conducting surface. Upon suitable external excitation, an oscillating electromagnetic field may be maintained within this space or resonator cavity. The resonators exhibit marked resonance effects and are characterized by the respective resonant frequency and band-width. In use, electromagnetic energy has to be coupled into and out of the filter and between the individual resonators of the filter.

[0004] The easiest way to achieve coupling between the resonators is the provision of an aperture in the wall between adjacent resonators which usually leads to magnetic coupling between these resonators. Therefore, the main way of coupling between the resonators is usually realized as magnetic coupling by means of coupling apertures.

[0005] However, there are also applications in which electric coupling is preferred as compared to magnetic coupling. This can be particularly helpful to effect cross-coupling for improving the filter characteristics. For cross-coupling negative coupling is required. Such electric coupling between two resonators may be achieved by provision of a capacitive coupling element which may comprise an elongated portion or pin. The coupling element is held in a dielectric mounting to avoid contact with the conductive walls of the resonator cavities. The mounting is placed in an opening cut out from an end of the side wall separating the two adjacent resonators. The elongated portion or pin extends into both cavities and provides electric coupling. Such arrangement is for example described in DE 196 02 815 A1. A similar arrangement is described in EP 0 525 416 B1. If an increased capacitive coupling strength is desired, such a coupling element may be provided with enlarged diameter end portions or disks at both ends of the elongated pin portion. Such coupling elements are for example disclosed in DE 21 61 792 A1.

[0006] Further, there are applications in which it is preferred to effect magnetic coupling by means of inductive wire coupling by providing an inductive probe. For example, in dielectric resonators capacitive probes are sometimes not applicable, so that for cross-coupling inductive wire coupling with sign change is required, as e.g. described in Walker, V., Hunter I.C.: "Design of cross-coupled dielectric-loaded waveguide filters", IEE Proceedings Microwaves, Antennas and Propagation, Vol. 148, No. 2, April 2001, pages 91-96 with reference to Figure 7.

[0007] In order for the filter to yield the desired filter characteristics, it is not only essential that the distinct resonators coupled together to form the filter have a predetermined resonant frequency. In addition, it is also of great importance to provide for adjustability of the coupling characteristics between the individual resonators. This is particularly true in view of the tendency towards ever decreasing bandwidths in combination with the need of high attenuation outside the pass-band and a low pass-band insertion loss in order to satisfy efficiency requirements and to preserve system sensitivity. For example, in communications networks based on cellular technology, such as the widely used GSM system, novel base station systems based on "software defined radio" should have as large a tuning range for all filter parameters as possible. This relates especially to tuning of the center frequencies of the resonators for switching the filter into other operational bands and to tuning of the coupling values due to changes of the fields inside the resonators at different frequencies.

[0008] For this reason, many conventional microwave filters have tunable coupling mechanisms.

[0009] US 6,150,907 discloses a coupling mechanism for coupling electromagnetic energy between the resonator cavities of two coupled TE_{001} or $TE_{01\delta}$ resonators, which coupling mechanism allows for adjustment of the magnitude and/or phase of the electromagnetic energy. The coupling mechanism comprises an elongate coupling element, which may be a dielectric rod or a conductive filament, and which passes through adjacent side walls of the coupled resonators and projects into both resonator cavities. Adjustment of the coupling characteristics is effected by shifting the entire coupling element as a whole along the axial direction of the two adjacent resonators, by rotating the entire coupling element as a whole about an axis perpendicular to the plane in which the coupling element extends, by bending the portions of the elongate coupling element projecting into the resonator cavities, or by a combination thereof.

[0010] US 6,924,718 B2 discloses a microwave filter comprising a plurality of electromagnetically coupled resonators, wherein at least two adjacent resonators are coupled by means of an elongate capacitive probe or an elongate inductive probe extending through the common side wall separating the cavities of the two resonators. The probe projects into both resonator cavities and is fixedly secured in the side wall, so that it is stationary. The elongate probe comprises a transverse bore located in the portion of the probe disposed within the side wall. A movable tuning conductor is received in the transverse bore and extends in the plane defined by the side wall, i.e. the tuning conductor does not project into any of the resonator cavities. The coupling characteristics of the probe may be adjusted by moving the tuning conductor within the plane defined by the side wall.

[0011] While these prior art coupling mechanisms provide for some degree of adjustability, the mechanisms are complex and thus expensive to manufacture and susceptible to failure in use. Further, the tuning range and the fine tuning capabilities are limited.

[0012] It is the object of the present invention to provide a microwave filter having a simple coupling mechanism, the coupling characteristics of which can be adjusted in a simple manner with a large tuning range, and which may be constructed in a cost-efficient way.

[0013] This object is achieved by a microwave filter with the features of claim 1. Further preferred embodiments of the invention are the subject-matter of the dependent claims.

[0014] A microwave filter according to the present invention comprises at least one resonator having electrically conductive walls defining a resonator cavity and a coupling mechanism for coupling electromagnetic energy into or out of the resonator cavity. The walls may be made of a conductive material or may be made of a dielectric material plated with a conductive material.

[0015] The coupling mechanism comprises a through bore extending through a wall portion of the resonator, which through bore extends transversely to the wall portion. Thus, there is a bore which passes completely through the wall portion to thereby connect the resonator cavity with the exterior of the resonator. This through bore is preferably straight, but may also be curved. In the usual manner, the direction of extension of the through bore is understood as the direction from one opening of the through bore along the through bore to the opposite opening of the though bore.

[0016] The coupling mechanism further comprises a coupling element. This coupling element extends through the through bore and comprises a first elongate portion adjacent the opening of the through bore into the resonator cavity and a second elongate portion adjacent the opposite opening of the through bore. The first elongate portion projects at least partly into the resonator cavity, whereas the second elongate portion may or may not project from the opening of the though bore on the side of the wall portion opposite the resonator cavity. The first and the second elongate portion are electrically conductive. The coupling element is constructed such that electromagnetic energy coupled into one of the elongate portions is transferred to the second elongate portion. In this way, electromagnetic energy can be coupled from the outside into the resonator cavity and vice versa. The elongate portions are preferably rigid, but may also be flexible.

[0017] A dielectric mounting of the coupling mechanism is provided for securing the coupling element in the wall portion such that the coupling element is electrically isolated from the wall portion. This dielectric mounting may be arranged as an element in a larger through bore formed in the wall portion, i.e. as an element only partly filling a through bore formed in the wall portion, or the dielectric mounting may be disposed in a cut-out region of the wall portion with the through bore being provided in the dielectric mounting. In the latter case, the through bore extends through the wall portion, but is formed in the dielectric mounting, which itself can be regarded as forming a part of the wall portion. Thus, the through bore extending through the wall portion is to be understood as meaning that the through bore provides a path from one side of the wall portion to the other side of the wall portion.

[0018] Further, the coupling mechanism comprises an adjustment means that is adapted to allow for a selective change of the coupling characteristics of the coupling mechanism, such as for a change of the coupling strength.

[0019] According to the present invention, the adjustment means is adapted to cooperate with or act on the coupling element in such a manner that it is possible to displace the first elongate portion and the second elongate portion of the coupling element with respect to each other to thereby selectively advance the first elongate portion from the through bore further into the resonator cavity or further retract the first elongate portion from the resonator cavity into the through bore. This means, that it is possible to operate the adjustment means in order to increase or decrease, at the operator's option according to the requirements and to the desired change of coupling characteristics, the length of the part of the first elongate portion projecting from the through bore into the resonator cavity. In this context it should be noted that, as will be explained in more detail below, the first elongate portion and the second elongate portion may be separate, physically distinct members or parts which, possibly in combination with additional members or parts, together form the coupling element, or the first elongate portion and the second elongate portion may be sections of one integral piece which, alone or together with additional members or parts, forms the coupling element.

[0020] In other words, the adjustment means is adapted to change the length of the path defined by (a) starting from the outer terminal end of the first elongate portion disposed in the resonator cavity along the first elongate portion to the opening of the through bore into the resonator cavity, (b) then from this opening following the direction of extension of the through bore to, depending on whether or not the second elongate portion projects from the through bore, the location of the outer terminal end of the second elongate portion in the through bore or the opposite opening of the through bore, and (c), in case the second elongate portion projects from this opening, from the opening along the second elongate portion to the outer terminal end of the second elongate portion. Thus, if the length of a central portion of the coupling element is understood as the length from the outer terminal end of the first elongate portion to the outer terminal end of the second elongate portion disregarding the course or run of the coupling element within the through bore deviating from the direction of extension of the through bore, the adjustment means is adapted to change the length of a central portion of the coupling element. Of course, if the first and the second elongate portion are the terminal end portions of the coupling element, the central portion spans the entire coupling element, so that in this case the length of the entire coupling element, understood in the above sense, can be changed, and the coupling element can selectively be gradually extended or shortened in its overall length. The same applies if further elements, such as e.g. capacitive disks or inductive wires, are secured to the outer ends of the elongate portions.

[0021] The capability of coupling electromagnetic energy from one of the two elongate portions to the other may preferably be realized by providing an electrical connection between the two elongate portions. In the alternative, the first elongate portion and the second elongate portion may be separated by a dielectric portion of the coupling element such that capacitive coupling is realized. Such a dielectric portion could e.g. comprise ceramic material to provide a large relative permittivity.

[0022] This coupling mechanism can be an input or output coupling mechanism for coupling electromagnetic energy from the exterior of the filter into a resonator or from a resonator to the exterior of the filter. Further, in case the filter comprises more than one resonator, the coupling mechanism can also be a coupling mechanism for coupling electromagnetic energy between adjacent resonators as described above. It is evident, that in case of more than one resonator, the filter may comprise several coupling mechanisms according to the present invention, some of which are input or output coupling mechanisms and some of which provide coupling between adjacent resonators.

[0023] The above construction provides the advantage of a simple and reliable coupling mechanism having a large tuning range.

[0024] For a coupling mechanism serving as an input or output coupling mechanism, it is preferred that the second elongate portion terminates in a connector component to thereby form an input or output coupling mechanism. The connector component can be constituted by a part of or the entire second elongate portion, or the connector component can be a component secured to the outer terminal end of the second elongate portion. Usually, the connector component will advantageously be secured to and thus stationary with respect to the wall portion. In view of the first and/or the second elongate portion moving during adjustment, it is preferred that the connector component or the second elongate portion has a bend formed therein to allow for compensation of the movement of portions of the coupling element to avoid damaging the connection of the connector component to the wall portion.

[0025] It is preferred that at least one of the resonators is electromagnetically coupled by means of its coupling mechanism to an adjacent resonator, wherein the coupling mechanism is disposed in a common wall portion separating the resonator cavities of the two resonators and wherein the second elongate portion of the coupling element projects from the through bore into the resonator cavity of the adjacent resonator. Thus, the microwave filter comprises at least one coupling mechanism of the above construction which serves as a coupling mechanism between the two resonator cavities of adjacent resonators. The coupling element of such a coupling mechanism projects from the through bore into both resonator cavities.

[0026] In a preferred embodiment, the first elongate portion and the second elongate portion are opposing end portions of the coupling element.

[0027] In a preferred embodiment, the coupling element is an elongate member, and the first elongate portion and the second elongate portion are portions of the elongate member. In other words, the two elongate portions are sections of the same elongate member. For this case, a preferred adjustment means is adapted to coil and uncoil a portion of the elongate member between the first and the second elongate portion or to displace a portion of the elongate member between the first and the second elongate portion transversely to the direction of extension of the through bore by e.g. forming a loop. In this way, the extension of the portion of the elongate member between the first and the second elongate portion in the direction of extension of the through bore is changed, and the first and the second elongate portion are thereby displaced with respect to each other.

[0028] In a preferred embodiment, the coupling element is a capacitive coupling element. Such a capacitive coupling element could e.g. comprise a disk-shaped portion located at the outer terminal end of the first and/or the second elongate portion. In a further preferred embodiment, the coupling element is an inductive coupling element. In such an inductive coupling element, the first and/or the second elongate portion could e.g. advantageously terminate in a flexible, electrically conductive wire electrically connected to a wall portion of the resonator. These flexible, electrically conductive wires can be components attached to the outer terminal end of the respective elongate portion, or they can be part of the respective elongate portion or the elongate portion itself. It is to be noted that in case of e.g. a flexible wire attached to a rigid elongate rod, it is equally possible to regard the combination of flexible wire and elongate rod as the elongate portion in the sense of the present invention, or to regard just the elongate rod as the elongate portion in the sense of the present invention to which the wire is attached.

[0029] In a preferred embodiment, the adjustment means is adapted to be operable to either simultaneously advance both elongate portions out of the through bore or simultaneously retract both elongate portions into the through bore, depending on the manner in which the adjustment means is operated. In an alternative embodiment, the adjustment means is adapted to be operable to move the first elongate portion, while the second elongate portion is not moving. In the latter case, the second elongate portion is preferably fixedly secured to the wall portion or dielectric mounting.

[0030] In a further preferred embodiment, the adjustment means is adapted to be operable to selectively increase and decrease the length of the coupling element from the outer terminal end of the first elongate portion along the coupling element to the outer terminal end of the second elongate portion. This can e.g. be achieved by a telescoping arrangement or, as will be explained in more detail below, by increasing and decreasing the extension of a region of overlap of the first and the second elongate portion partly running side by side.

[0031] It is preferred that the first and second elongate portions are both straight. This construction is particularly simple. However, for some applications, such as e.g. an application necessitating a curved through bore, it may also be advantageous if the first and second elongate portions are both at least partly curved.

[0032] In a preferred embodiment, the first elongate portion and the second elongate portion are physically separate and distinct components of the coupling element arranged such that they overlap each other along at least a part of their length and that they extend parallel to the direction of extension of the through bore. The adjustment means is then adapted to be operable to shift one of these components or both components along the direction of extension of the through bore in order to increased and decreased the region of overlap. For such a construction, it is advantageous, if the adjustment means is adapted to be operable to shift the two components in opposite directions with respect to each other. In any case, in a particularly preferred form of this embodiment the two components are toothed racks disposed laterally offset from each other with their toothings facing each other, and the coupling element further includes a pinion which is electrically conductive to effect an electrical connection between the toothed racks or may be made of or comprise dielectric material to effect capacitive coupling between the toothed racks. The pinion is located between the toothed racks and engages the toothings of the two racks, such that upon rotation of the pinion the two toothed racks are displaced with respect to each other. The adjustment means is adapted to be operable to effect rotation of the pinion. While in this preferred form two toothed racks are provided, it is of course also possible that only the first elongate portion is a toothed rack, and that the adjustment means is operable to effect rotation of a pinion engaging the toothing of this toothed rack, such that upon rotation of the pinion the toothed rack is displaced with respect to the second elongate portion. Providing only on toothed rack may be advantageous e.g. for an input or output coupling mechanism.

[0033] For such embodiments, in case the pinion has to provide for an electrical connection between the two elongate portions, the pinion may be made of conductive material or plated with conductive material, and in case the pinion has to provide for a capacitive connection between the two elongate portions, the pinion may be made of or comprise on its outside dielectric material, such as e.g. ceramic material.

[0034] Further, the pinion is preferably formed as the end portion of a rod. The rod extends in a bore which is formed in the dielectric mounting and which extends perpendicularly to the direction of extension of the through bore. The end portion of the rod opposite the pinion is accessible from outside the filter for rotating the rod and thereby the pinion.

[0035] For all of the above embodiments including a pinion and one or two toothed racks, it may be advantageous in some cases to replace the toothed rack(s) with a rod or other elongate element not having a toothing and the pinion with a wheel not having a toothing. In these cases, the wheel is arranged to frictionally engage the rod(s) or other elongate element(s). In case of two such rods or other elongate elements, the wheel is positioned between them. It is preferred that such wheel is made of a material with a high coefficient of friction, such as rubber material, or comprises such material on its outside surface. With such a construction, the fine tuning capabilities of the coupling mechanism may be enhanced.

[0036] With the coupling element including a pinion and one or more toothed racks or a wheel frictionally engaging one or more rods, a very small coupling mechanism can be realized which efficiently utilizes the small space available within microwave filters.

[0037] Although a pinion or possibly a wheel are preferred, it is also possible to replace the pinion or wheel with a different drive mechanism or actuator, such as a piezoelectric actuator, e.g. a linear piezoelectric motor. Such a drive mechanism or actuator preferably comprises one or more tips engaging the one or more toothed racks or rods in order to effect their movement. The tips may engage the toothing of a toothed rack or they may be friction tips frictionally engaging a rod or other elongate element. There may e.g. be one tip for effecting movement in both directions, or there may e.g. be separate tips for the two directions of movement.

[0038] In a preferred embodiment, the dielectric mounting is made from PTFE (polytetrafluor ethylene), polyethylene, FEP (fluorinated ethylene-propylene) or PEEK (polyether etherketone).

[0039] In a further preferred embodiment, the dielectric mounting is secured in the wall portion in such a manner that it may be rotated together with the coupling element to thereby change the orientation of the first and second elongate portions of the coupling element within the resonator cavities. In this way, an additional tuning possibility is provided, thereby increasing ease of tuning and the tuning range.

[0040] It is preferred that the adjustment means is disposed entirely or partly within the wall portion, i.e. in the through bore and/or in an additional bore or cavity formed in the wall portion. Further, the adjustment means is arranged to act on the coupling element within the wall portion, such as e.g. within the through bore. In any case, the adjustment means preferably does not protrude from the wall portion into an adjacent resonator cavity. However, it might be advantageous if a part of the adjustment means protrudes to the outside of the filter to be easily accessible for operating the adjustment means.

[0041] A preferred microwave filter includes a plurality of coupled resonators including at least one combline resonator and/or at least one dielectric resonator, and at least one of coupling mechanism according to the present invention arranged to provide for coupling of electromagnetic energy into or out of a combline resonator and/or a dielectric resonator.

[0042] In any case, it is to be understood that the microwave filter may of course comprise several coupling mechanisms according to the present invention, where the various coupling mechanisms may be identical or different in construction. Thus, the coupling mechanisms could comprise different of the above-described features. For example, some of the coupling mechanisms could comprise a capacitive coupling element and some of the coupling mechanisms could comprise an inductive coupling element.

[0043] The invention is in the following described by way of example with reference to preferred embodiments shown in the drawings in which

Figure 1 is a perspective view of a combline resonator microwave filter according to one embodiment of the present invention with the cover of the filter removed, wherein a coupling mechanism is provided having a capacitive coupling element,

Figure 2 is a perspective view of the coupling mechanism of Figure 1 shown isolated from the remainder of the filter,

Figure 3 is a perspective explosive view of the coupling mechanism shown in Figure 2,

Figure 4 is a perspective view of the capacitive coupling element and part of the adjustment means of the coupling mechanism shown in Figures 1 to 3,

Figure 5 is a top view of the combline filter of Figure 1,

Figure 6 is a perspective view of a dielectric TM mode filter with a wall portion removed comprising two resonator cavities coupled by means of a coupling mechanism having an inductive coupling element,

Figure 7 is part sectional view of a combline resonator filter comprising an input coupling mechanism having a capacitive coupling element, and

Figure 8 is an enlarged sectional view of the combline resonator filter shown in Figure 7.

[0044] Figure 1 shows a perspective view of a portion of a combline resonator microwave filter 1 according to the present invention with the upper cover of the filter removed. As can be ascertained from Figure 1, the filter 1 comprises side walls 2 and a bottom wall 3 which, together with the upper cover, define a plurality of resonator cavities 4. In each resonator cavity 4, an inner conductor 5 is disposed which is secured and electrically connected to the bottom wall 3 and extends upwardly therefrom along the central longitudinal axis of the resonator cavity 4. Each resonator cavity 4 together with the corresponding inner conductor 5 and wall portions 2, 3 (and the cover) constitutes a combline resonator or combline resonant section.

[0045] Between some of the adjacent combline resonators, a coupling window or coupling iris 6 is formed in the common side wall 2 separating the respective resonator cavities 4 to thereby form the main coupling path of the filter in the usual manner. In addition to these coupling mechanisms, a further coupling mechanism 7, providing electrical coupling, is disposed in the side wall 2 between two combline resonators not adjacent along the main coupling path to thereby provide for cross-coupling. This coupling mechanism 7 is a coupling mechanism according to the present invention and is shown isolated in

Figure 2 and in more detail in the exploded illustration shown in Figure 3.

[0046] As can be seen in Figures 2 and 3, the coupling mechanism 7 comprises a cylindrical dielectric mounting body 8 which has a cylindrical through bore 9 extending perpendicularly to the axis of the cylinder 8. Further, the coupling mechanism 7 comprises an electrically conductive coupling element 10 in the form of a capacitive probe, which is composed of three separate parts, namely a first electrically conductive rigid elongate portion or rod 11a having a capacitive disk 12a secured to its one end, a second electrically conductive rigid elongate portion or rod 11b having a capacitive disk 12b secured to its one end, and an electrically conductive pinion 13, which is formed on the end of a rod 14. At least the surface of pinion 13 must have good electrical conductivity. The coupling element 10 is shown in the assembled state, but with the dielectric mounting body 8 removed in Figure 4. Each rigid elongate portion or rod 11a, 11b is constructed as a part cylinder having a toothing 15a and 15b, respectively, formed on its flat surface along a part of its length. Thus, the two rigid elongate portions or rods 11a, 11b are toothed racks. In the assembled state, the two toothed racks 11a, 11b are arranged such that their toothings 15a, 15b face each other, with the pinion 13 disposed between the toothed racks 11a, 11b in meshing engagement with both toothings 15a, 15b (see Figure 4) .

[0047] The through bore 9 is dimensioned to receive the toothed racks 11a, 11b and the pinion 13 in the state shown in Figure 4. The dimensions of the toothed racks 11a, 11b and the pinion 13 are chosen such that there is only a small clearance between the curved outside surfaces of the toothed racks 11a, 11b and the inside surface of the through bore 9. In this way, the toothed racks 11a, 11b and the pinion 13 are secured against lateral movement. Further, because the pinion 13 is in meshing engagement with the toothings 15a, 15b, the toothed racks 11a, 11b cannot move freely in the axial direction, i.e. the direction of extension, of the through bore 9. As shown in Figure 2, each toothed rack 11a, 11b is disposed adjacent one of the two opposing openings 16 of the through bore 9 and projects from the through bore 9 into the respective resonator cavity 4. Thus, each toothed rack 11a, 11b extends partly within the through bore 9 and partly in the resonator cavity 4. The capacitive disks 12a, 12b are located inside the respective resonator cavity 4.

[0048] It is evident that due to this arrangement, upon rotation of the pinion 13, the toothed racks 11a, 11b move in opposite directions parallel to the axial direction of through bore 9. In this way, depending on the chosen direction of rotation of the pinion 13, the overall length of coupling element 10, i.e. the distance between the two capacitive disks 12a, 12b, is increased or decreased. Thus, with the center of the coupling element 10 being fixed by the pinion 13, the toothed racks 11a, 11b are gradually further advanced out of the through bore 9 into the respective resonator cavity 4 or are gradually further retracted into the through bore 9, thereby increasing or decreasing the distance between the capacitive disks 12a, 12b and the side wall 2 to change the coupling characteristics. The basic principle behind this embodiment as compared to prior art coupling mechanisms is that the coupling element is split up into two parts which are moveable against each other by means of a pinion located between them in the center of the coupling element to increase or decrease the length of the coupling element.

[0049] As shown in Figures 2 and 3, the cylindrical mounting body 8 further has a cut 17 which extends from one of its end faces and merges into through bore 9, and a cylindrical bore 18 which likewise extends from the same end face of the mounting body 8 along the axial direction of the mounting body 8 before merging into through bore 9. The cylindrical bore 18 is dimensioned to receive the rod 14 and the pinion 13 with a small clearance to allow for rotation of the rod 14 inside the bore 18. This arrangement greatly facilitates securing the coupling element 10 in the mounting 8 without sacrificing the reliability of the connection. The mounting body 8 is formed from a material, which enables elastically spreading away the two cylinder portions separated by the cut 17 to form a gap and to thereby temporarily expand the through bore 9 such that the toothed racks 11a, 11b can be inserted into the through bore 9 in their appropriate position but with a distance between the toothings 15a, 15b greater than the diameter of pinion 13. Subsequently, the rod 14 can be inserted through the cylindrical bore 18 until the pinion 13 is positioned in the center of expanded through bore 9. Then, the two spaced apart cylinder portions can be released to close the gap and to return through bore 9 to its normal dimensions. In this way, the toothings 15a, 15b are brought into meshing engagement with pinion 13 and the coupling element 10 is secured in the mounting body 8.

[0050] On the end opposite the pinion 13, the rod 14 has an enlarged diameter portion 19 with a slit 20. Although not shown in the Figures, the bore 18 in the mounting body 8 comprises a lower section and an enlarged diameter upper section, thereby forming a shoulder on which the enlarged diameter portion 19 can rest. By means of this shoulder, the axial position of the pinion 13 within through bore 9 is determined. The rod 14 can be easily rotated by means of e.g. a screw driver inserted through the bore 18 and engaging slit 20 (see Figure 5). Rod 14 with enlarged diameter portion 19 and slit 20 forms an adjustment means for changing the length of coupling element 10 and, thus, the coupling characteristics of the coupling mechanism 7. The enlarged diameter portion 19 and the remainder of the rod 14 should have no electrical contact with the wall portions of the filter. Therefore, the enlarged diameter portion 19 should be disposed sufficiently deep inside the mounting body 8. In the alternative, the entire rod 14 with the exception of pinion 13 could be made of dielectric material. For example, the rod 14 including the pinion 13 could be made of dielectric material, with only the pinion 13 being plated with conductive material such as e.g. silver or copper.

[0051] It is to be noted that the above construction of the dielectric mounting 8 is advantageous not only in this particular embodiment, but also for all other embodiments of the present invention. For example, a coupling element that does not comprise several parts but is formed in one piece, can be easily secured by spreading away the two cylinder portions separated by the cut 17 to form a gap sufficiently large to allow a center portion of the coupling element to be slid through the cut 17 into through bore 9. However, the dielectric mounting 8 could also be constructed differently. For example, it could comprise a lower part having a bore for the toothed racks and a bore for the pinion, and an upper part which ensures that the enlarged diameter portion 19 of rod 14 cannot move upwardly in order to provide mechanical stability and avoid contact with the wall portions of the filter.

[0052] In the assembled state shown in Figure 2, the coupling mechanism 7 is secured in the side wall 2 separating the adjacent resonator cavities 4 to be coupled by fitting the mounting body 8 into an opening 21 which is cut out from the upper end of the side wall 2 (see Figure 1). The opposing surfaces of the cut-out 21 in the side wall 2 are adapted to conform to the surface of the cylindrical mounting body 8 and are dimensioned to receive this cylindrical mounting body 8 in a press fitting manner. This ensures that the coupling mechanism 7 is securely held in place once the mounting 8 is in its press-fitting seat in the cut-out 21. The through bore 9 of the mounting 8 extends transversely to the side wall 2 and constitutes a through bore through the side wall 2. This state is shown in Figures 4 and 5.

[0053] The cylindrical shape of the mounting body 8 together with the complementary cylinder segment shape of the opposing surfaces of the cut-out 21 provide for a press-fitting seat of the mounting body 8. Nevertheless, it is possible to turn the mounting body 8 inside the cut-out 21 in order to alter the orientation or direction of the coupling element 10. Since this also alters the locations of the capacitive disks 12a, 12b inside the resonator cavities 4, the capacitive coupling strength may be altered. This can also be achieved if the cover (not shown) is already closed and fixed, if an opening is provided in the cover in the area over the mounting body 8. This is also advantageous in case access to the enlarged diameter portion 19 of adjustment rod 14 without the need to remove the cover is desired.

[0054] A further advantage of the cylindrical mounting body 8 is that it can be received in openings which are formed in side walls of different thicknesses. In a side wall of greater thickness a larger part of the cylinder surface is surrounded by the opposing surfaces of the opening in the side wall, whereas in thinner side walls only a relatively small part of the cylinder surface is engaged by the opposing surfaces of the opening, whereas the radius of curvature of the opposing surfaces of the opening in the side wall is always the same and equal to the radius of the cylinder.

[0055] Figure 6 shows a perspective view of a dielectric TM mode microwave filter 1' according to the present invention with a wall portion removed. The dielectric resonator filter 1' comprises two resonator cavities 4 coupled by means of a coupling mechanism 7' having an inductive coupling element 10'. The filter 1' comprises side walls 2, a bottom wall 3 and a cover 22 defining the resonator cavities 4. In each resonator cavity 4, a dielectric rod 23 is disposed and extends between the bottom wall 3 the cover 22. Each resonator cavity 4 together with the corresponding dielectric rod 23 and wall portions 2, 3, and 22 constitutes a dielectric resonator or dielectric resonant section.

[0056] The coupling mechanism 7', providing magnetic coupling, is disposed in the side wall 2 between the two adjacent dielectric resonators. It is constructed identically to the coupling mechanism 7 shown in Figures 1 to 5 with the exception of the capacitive disks 12a, 12b being replaced with flexible, electrically conductive wires 24a, 24b. One end of the wires 24a, 24b is secured, e.g. by soldering, to the outer terminal end of toothed racks 11a and 11b, respectively, and the other end of wires 24a, 24b is secured, e.g. by soldering or screwing, to one of the wall portions 2, 3, or 22. Due to the movement of the toothed racks 11a, 11b upon adjustment, the wires should be of sufficient flexibility and length to allow for compensation of the movement.

[0057] Figures 7 and 8 show a further embodiment of the present invention, in which a coupling mechanism 7" is provided as an input or output coupling mechanism to the first combline resonator or combline resonant section of a combline resonator microwave filter 1". Evidently, Figures 7 and 8 could also show an edge region of the combline filter 1 shown in Figures 1 to 5.

[0058] The combline filter 1'' comprises a side wall 2'' of increased thickness as compared to side walls 2 separating adjacent resonator cavities 4. While the construction of the filter 1'' and the arrangement of coupling mechanism 7" in the side wall 2'' is largely identical to the construction shown in Figures 1 to 5, the mounting body 8 is disposed completely inside the side wall 2'', and the through bore 9 through the mounting body 8 is not identical with the through bore through the side wall 2" . Rather, a through bore 9" is formed through the side wall 2'' which has a larger diameter than through bore 9. Further, the coupling mechanism 7" is constructed identically to the coupling mechanism 7 shown in Figures 1 to 5 with the exception of one of the toothed racks 11a, 11b being replaced with a flexible, electrically conductive wire 25 and of the other toothed rack 11b" not having a capacitive disk at its end (although a capacitive disk could be provided to increase the coupling strength). Although not shown, a suitable stationary toothing is present inside through bore 9 of mounting body 8, and the pinion 13 is in meshing engagement with this toothing and the toothing 15b'' of toothed rack 11b".

[0059] The wire 25 is the inner conductor of a coaxial connector 27 and is connected, e.g. by soldering, to the end of toothed rack 11b" opposite the end projecting into the resonator cavity 4. In the wire 25, a loop or bend 26 is formed to allow for compensation of the motion of the toothed rack 11b" upon rotation of pinion 13. Another possibility is to provide an inflexible inner conductor which is arranged such that it is pressed against the moving toothed rack 11b" to provide a sliding electrical contact. In this embodiment, the pinion 13 is preferably not conductive and advantageously made of nonconductive material.

[0060] It is evident that coupling mechanism 7 " provides for capacitive coupling. However, it could also be realized as inductive coupling as described above.

Claims

1. Microwave filter comprising at least one resonator having

- electrically conductive walls (2, 3) defining a resonator cavity (4) and
- a coupling mechanism (7, 7', 7") for coupling electromagnetic energy into or out of the resonator cavity (4), wherein the coupling mechanism (7, 7', 7") comprises

(a) a through bore (9, 9") extending through a wall portion (2) of the resonator extending transversely to the wall portion (2),
(b) a coupling element (10, 10') extending through the through bore (9, 9'') and comprising a first elongate portion (11b, 11b") adjacent the opening of the through bore (9, 9") into the resonator cavity (4) and a second elongate portion (11a, 25) adjacent the opposite opening of the through bore (9, 9"), wherein the first elongate portion (11b, 11b") projects at least partly into the resonator cavity (4), and wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are electrically conductive and arranged such that electromagnetic energy can be transferred between the first elongate portion (11b, 11b") and the second elongate portion (11a, 25),
(c) a dielectric mounting (8) for securing the coupling element (10, 10') in the wall portion (2) such that the coupling element (10, 10') is electrically isolated from the wall portion (2), and
(d) an adjustment means (14) operable to selectively change the coupling characteristics of the coupling mechanism (7, 7', 7"),

characterized in that the adjustment means (14) is operable to displace the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) with respect to each other to thereby selectively advance the first elongate portion (11b, 11b") from the through bore (9, 9") into the resonator cavity (4) or retract the first elongate portion (11b, 11b") from the resonator cavity (4) into the through bore (9, 93").

2. Microwave filter according to claim 1, wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are electrically connected to each other.

3. Microwave filter according to claim 1, wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are separated by a dielectric portion of the coupling element (10, 10').

4. Microwave filter according to any of claims 1 to 3, wherein the second elongate portion (25) terminates in a connector component (27) to thereby form an input or output coupling mechanism.

5. Microwave filter according to any of claims 1 to 3, wherein at least one of the resonators is electromagnetically coupled by means of its coupling mechanism (7, 7') to an adjacent resonator, wherein the coupling mechanism (7, 7') is disposed in a common wall portion (2) separating the resonator cavities (4) of the two resonators and wherein the second elongate portion (11a) of the coupling element (10, 10') projects from the through bore (9) into the resonator cavity (4) of the adjacent resonator.

6. Microwave filter according to any of the preceding claims, wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are opposing end portions of the coupling element (10, 10').

7. Microwave filter according to any of the preceding claims, wherein the coupling element is an elongate member, and wherein the first elongate portion and the second elongate portion are portions of the elongate member.

8. Microwave filter according to claim 7, wherein the adjustment means is operable to coil and uncoil a portion of the elongate member between the first and the second elongate portion or to displace a portion of the elongate member between the first and the second elongate portion transversely to the direction of extension of the through bore.

9. Microwave filter according to any of the preceding claims, wherein the coupling element (10) is a capacitive coupling element.

10. Microwave filter according to claim 9, wherein the first (11b) and/or the second elongate portion (11a) terminates in a disk-shaped portion (12a, 12b).

11. Microwave filter according to any of claims 1 to 8, wherein the coupling element (10') is an inductive coupling element.

12. Microwave filter according to claim 11, wherein the first (11b) and/or the second elongate portion (11a) terminates in a flexible, electrically conductive wire (24a, 24b) electrically connected to a wall portion of the resonator.

13. Microwave filter according to any of the preceding claims, wherein the adjustment means is operable to simultaneously either advance both elongate portions (11b, 11b"; 11a, 25) out of the through bore (9, 9") or retract both elongate portions (11b, 11b"; 11a, 25) into the through bore (9, 9").

14. Microwave filter according to any of claims 1 to 12, wherein the adjustment means is operable to move the first elongate portion, while the second elongate portion is not moving.

15. Microwave filter according to claim 14, wherein the second elongate portion is fixedly secured to the wall portion.

16. Microwave filter according to any of the preceding claims, wherein the adjustment means (14) is operable to selectively increase and decrease the length of the coupling element (10, 10') from the outer terminal end of the first elongate portion (11b, 11b") along the coupling element (10, 10') to the outer terminal end of the second elongate portion (11a, 25).

17. Microwave filter according to any of the preceding claims, wherein the first and second elongate portions are both either straight or both at least partly curved.

18. Microwave filter according to any of the preceding claims, wherein the first elongate portion (11b, 11b") and the second elongate portion (11a, 25) are separate components of the coupling element (10, 10') arranged such that they overlap each other along at least a part of their length, wherein the adjustment means (14) is operable to shift at least one of these components (11b, 11b"; 11a, 25) along the extension of the through bore (9, 9") such that the region of overlap can be increased and decreased.

19. Microwave filter according to claim 18, wherein the adjustment means (14) is operable to shift the two components (11b, 11b"; 11a, 25) in opposite directions with respect to each other.

20. Microwave filter according to claim 18 or claim 19, wherein the two components (11a, 11b) are toothed racks disposed laterally offset from each other with their toothings (15a, 15b) facing each other, wherein the coupling element (10, 10') further includes a pinion (13) which is electrically conductive to effect an electrical connection between the toothed racks (11a, 11b) or which is insulating to effect a capacitive coupling between the toothed racks (11a, 11b), and which is located between the toothed racks (11a, 11b) and engaging the toothings (15a, 15b) of the two racks (11a, 11b), such that upon rotation of the pinion (13) the two toothed racks (11a, 11b) are displaced with respect to each other, wherein the adjustment means (14) is operable to effect rotation of the pinion (13).

21. Microwave filter according to any of claims 1 to 17, wherein the first elongate portion (11b") is a toothed rack, and wherein the adjustment means (14) is operable to effect rotation of a pinion (13) engaging the toothing (15b'') of the toothed rack (11b"), such that upon rotation of the pinion (13) the toothed rack (11b") is displaced with respect to the second elongate portion (25).

22. Microwave filter according to claim 20 or claim 21, wherein the pinion (13) is made of conductive material or plated with conductive material.

23. Microwave filter according to any of claims 20 to 22, wherein the pinion (13) is formed as the end portion of a rod (14), wherein the rod (14) extends in a bore (18) formed in the dielectric mounting (8) and extending perpendicularly to the through bore (9), wherein the end portion (19) of the rod (14) opposite the pinion (13) is accessible to rotate the rod (14) and thereby the pinion (13) .

24. Microwave filter according to any of the preceding claims, wherein the dielectric mounting (8) is made from PTFE (polytetrafluor ethylene), polyethylene, FEP (fluorinated ethylene-propylene) or PEEK (polyether etherketone).

25. Microwave filter according to any of the preceding claims, wherein the dielectric mounting (8) is secured in the wall portion (2) in such a manner that it may be rotated together with the coupling element (10, 10') to thereby change the orientation of the first (11b, 11b") and second elongate portions (11a, 25) of the coupling element (10, 10') within the resonator cavities (4).

26. Microwave filter according to any of the preceding claims, wherein the adjustment means (14) is arranged at least partly in the wall portion (2), is arranged to act on the coupling element (10, 10') within the wall portion (2), and does not protrude from the through bore (9, 9").

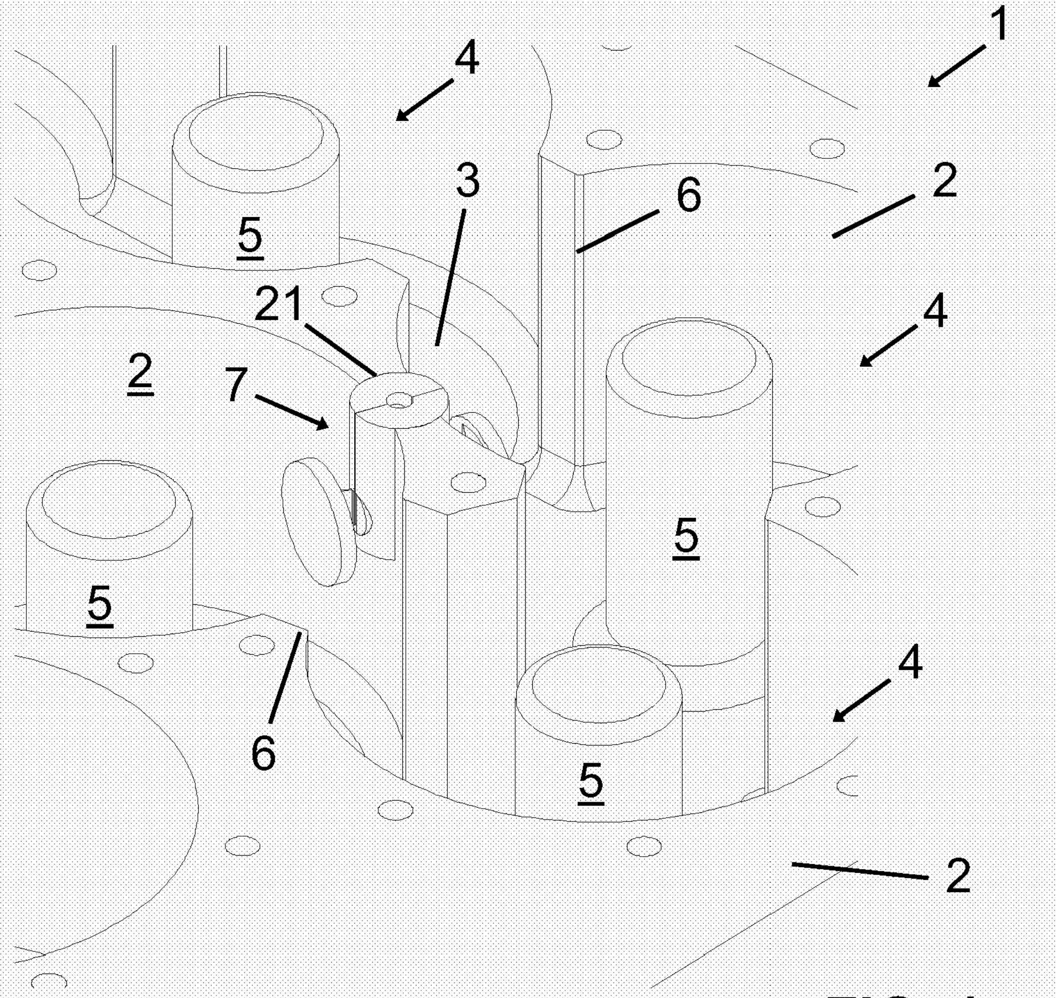


FIG. 1

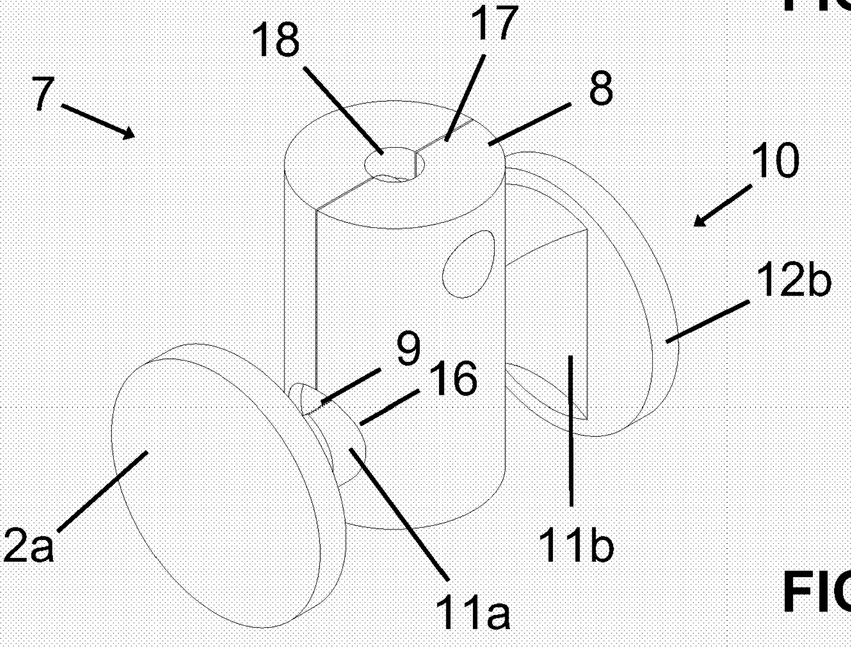


FIG. 2

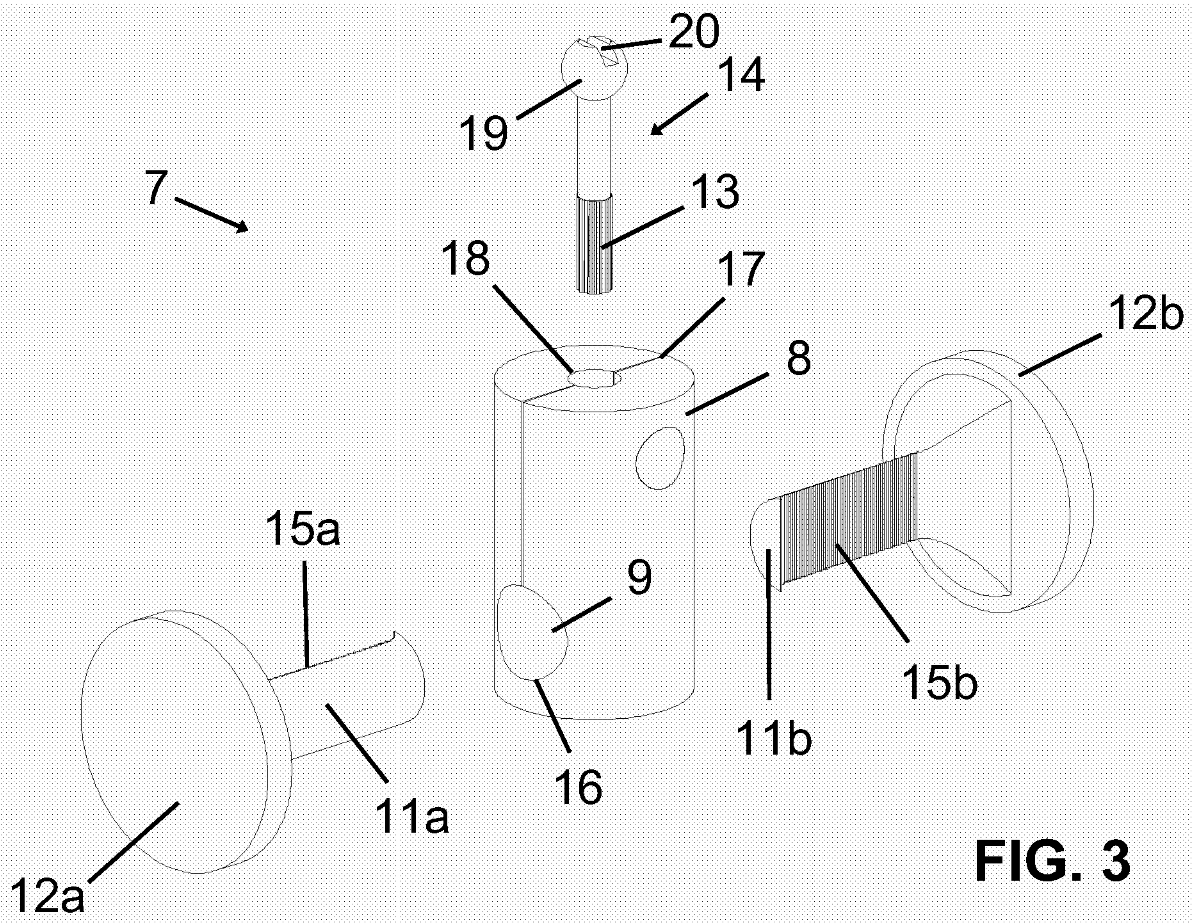
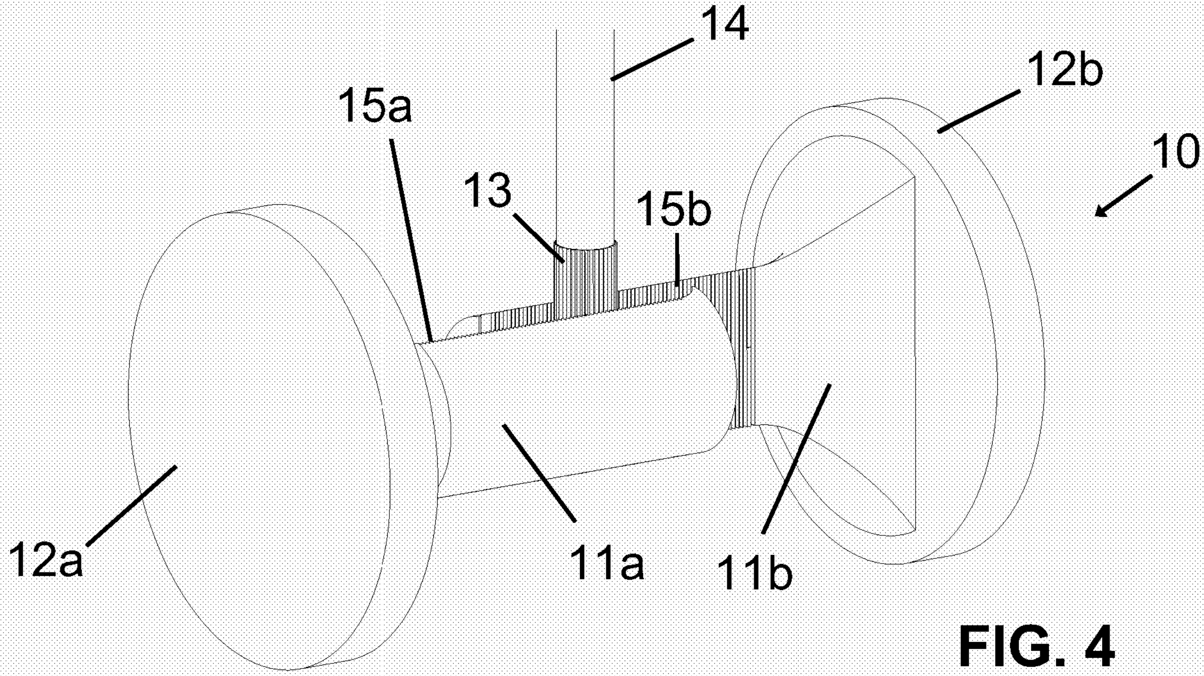

20
14
19
7
13
18
17
12b
8
15a
9
15b
11b
16
11a
12a

FIG. 3


14
12b
15a
10
13
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12a
11a
11b

FIG. 4

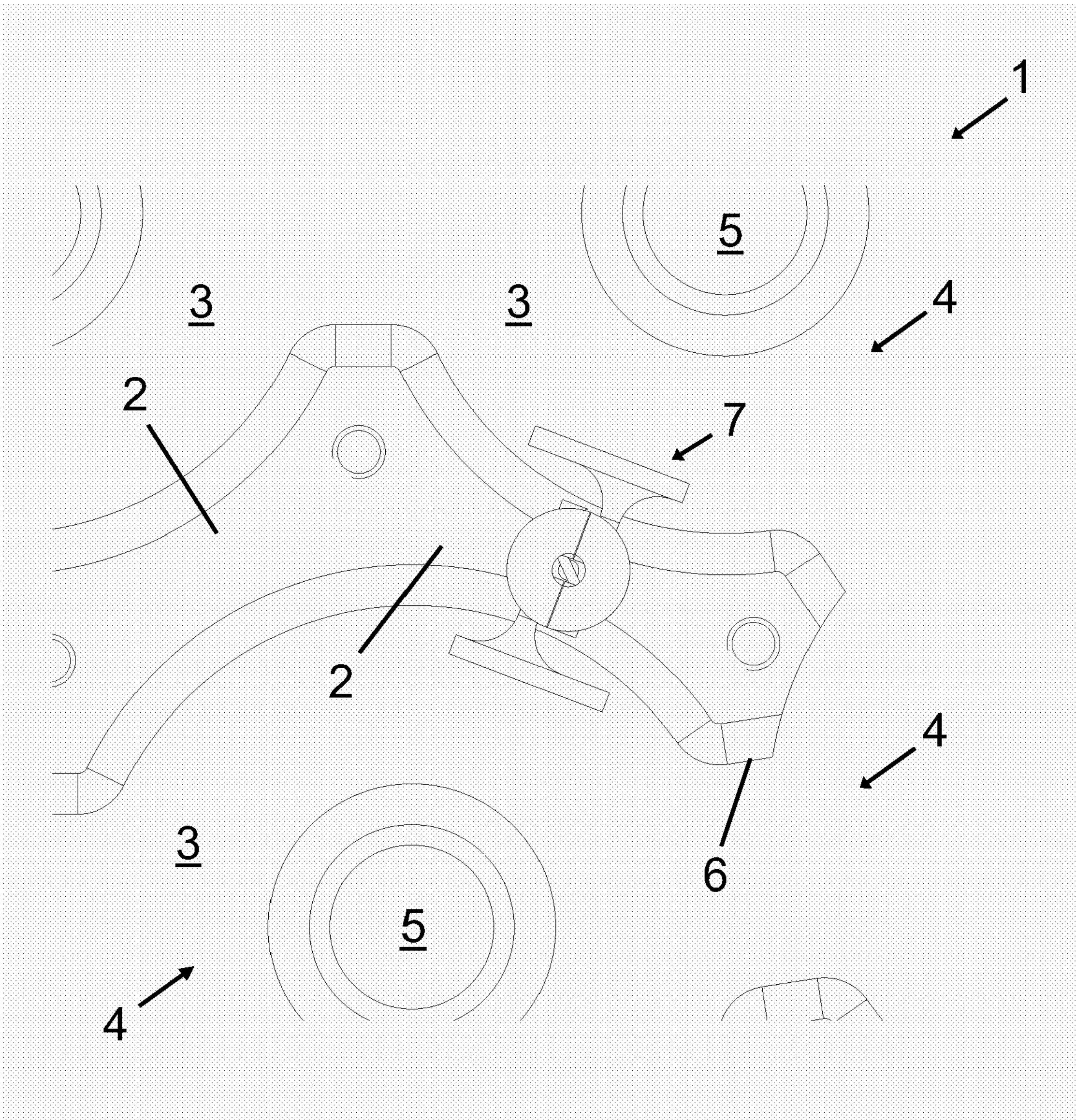

FIG. 5

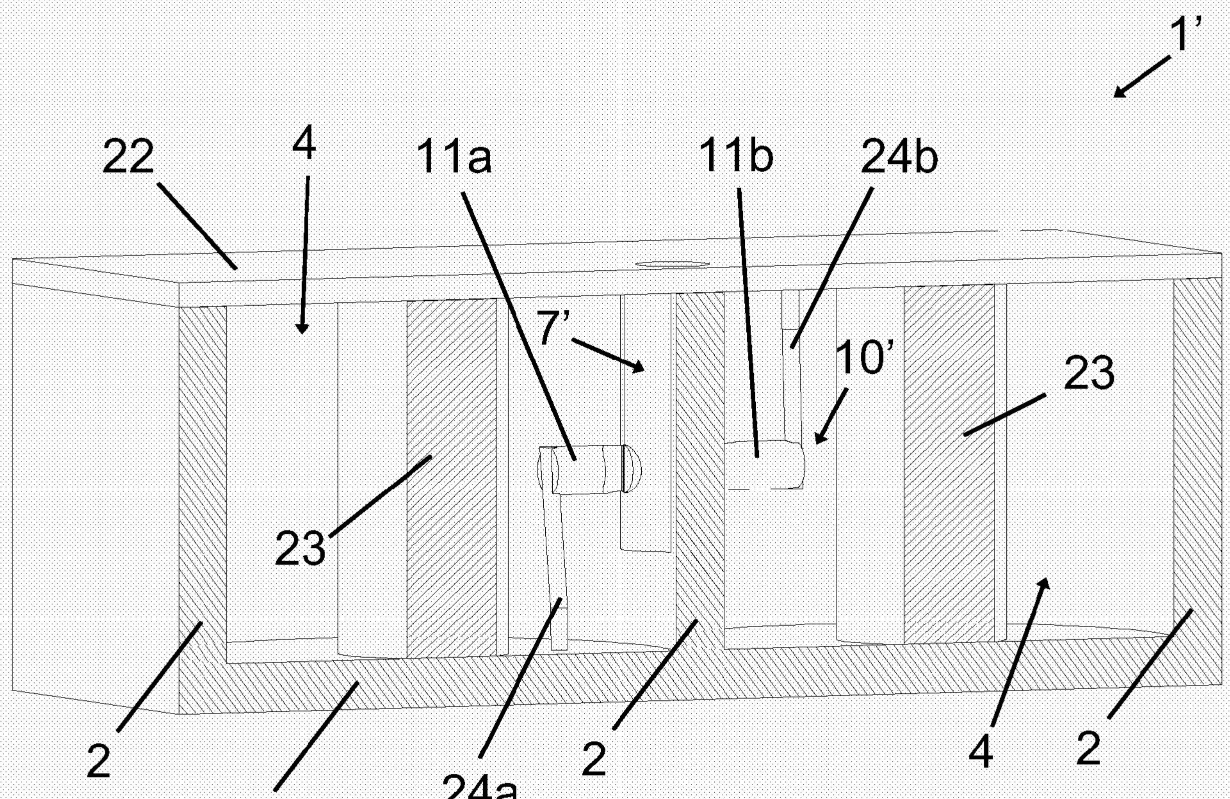

FIG. 6

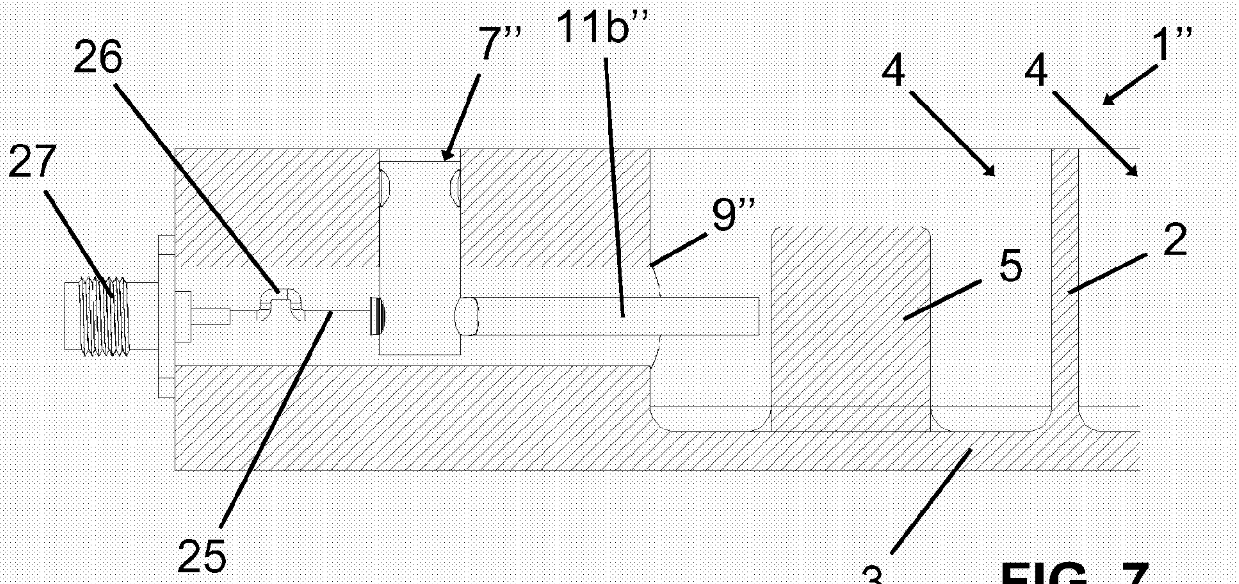

FIG. 7

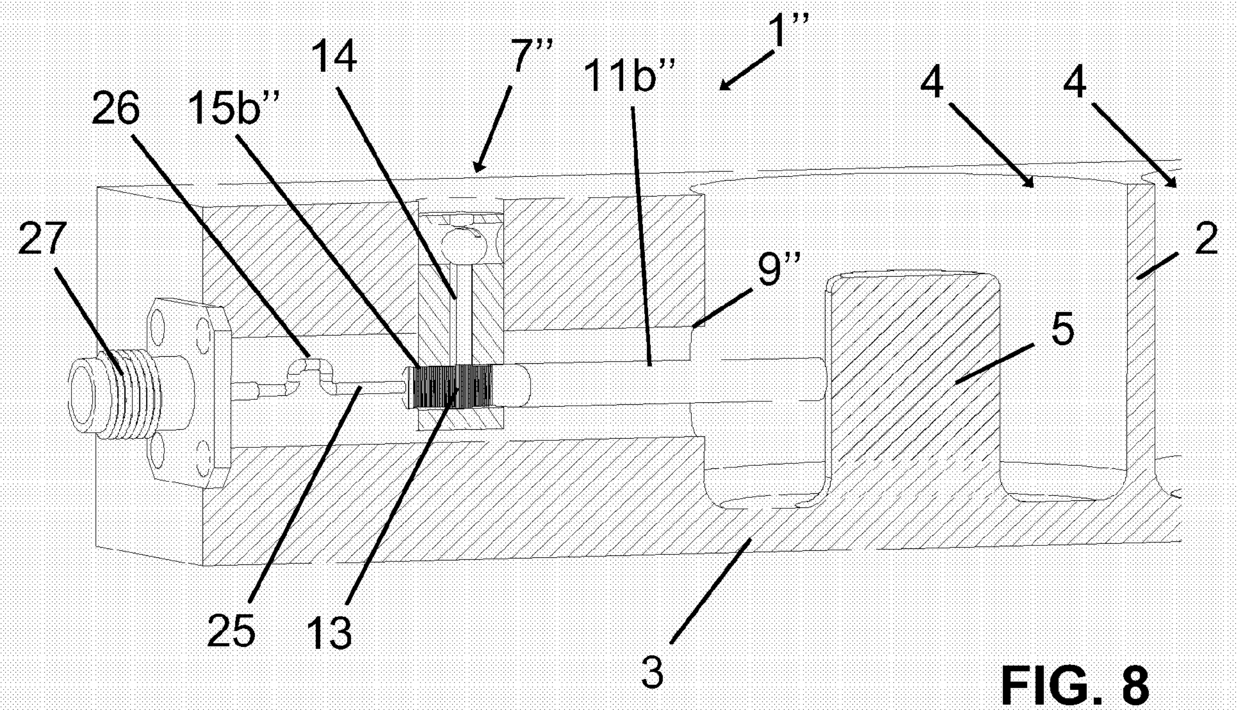

FIG. 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 11 9880

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	30 January 2007	PASTOR JIMENEZ, J

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