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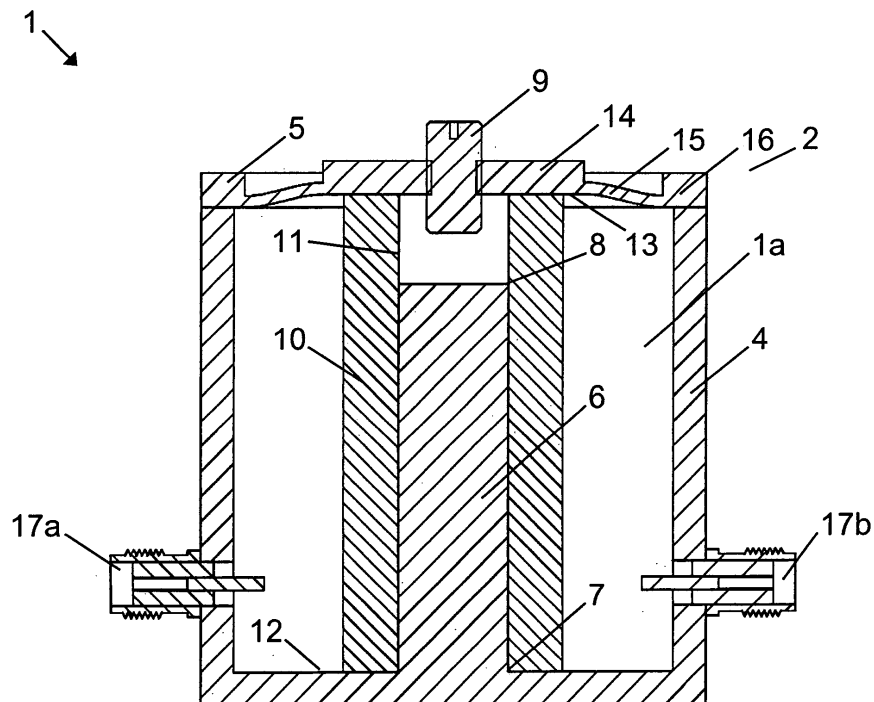
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(54) **Microwave filters with dielectric loads of same height as filter housing**

(57) The present invention relates to a coaxial resonator (1) comprising a conductive housing (2) defining a cavity (1a) and having a lower end wall (3), a sidewall (4) extending upwardly from the lower end wall (3), and an upper end wall (5). An inner conductor (6) is disposed within the housing (2) and extends upwardly from the

lower end wall (3). It is electrically connected to the lower end wall (3). A hollow dielectric element (10) surrounds the inner conductor (6) along its entire length. The hollow dielectric element (10) is mechanically secured within the cavity (1a) by clamping between the lower end wall (3) and the upper end wall (5).

**Fig. 1**

Description

[0001] The present invention relates to a coaxial resonator comprising a hollow dielectric element surrounding the inner conductor of the coaxial resonator along the entire length of the inner conductor, and to a microwave filter comprising a plurality of coupled resonators including at least one such coaxial resonator.

[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] For example, in communications networks based on cellular technology, such as the widely used GSM system, the coverage area is divided into a plurality of distinct cells. Each cell is assigned to a base station which comprises a transceiver that has to communicate simultaneously with a plurality of mobile devices located within its cell. This communication has to be handled with minimal interference. For example, base stations and mobile devices communicating based on GSM in the 900 MHz band must be protected from interference signals caused by communications based on GSM in the 1800 MHz band or UMTS. Moreover, the base stations and mobile devices should not transmit outside their designated frequency band. Therefore, the frequency range utilized for the communications signals associated with the cells is separated from adjacent frequencies by the use of microwave filters in the base station as well as in the mobile devices. Further, because GSM base stations transmit and receive simultaneously, the same microwave filters are also used to divide the frequency range into a first frequency band, that is used by the base station to transmit signals to the mobile devices (downlink), and a second frequency band, that is used by the mobile devices to transmit signals to the base station (uplink), in order to isolate the transmitter from the receiver. The filters must have a high attenuation outside their pass-band and a low pass-band insertion loss in order to satisfy efficiency requirements and to preserve system sensitivity. Thus, such communication systems require an extremely high frequency selectivity in both the base sta-

tions and the mobile devices which often approaches the theoretical limit.

[0004] Commonly, microwave filters include a plurality of resonant sections which are coupled together in various configurations: Each resonant section constitutes a distinct resonator and 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. The resonant sections or individual resonators' exhibit marked resonance effects and are characterized by the respective resonant frequency and band-width.

[0005] An example of one type of resonator element found in microwave filters including a plurality of coupled resonant sections is described in EP 1 505 687 A1. This resonator element is a dielectric resonator resonating in a TM-mode, such as the TM_{010} -mode, and can be utilized to build dielectric filters. The dielectric resonator comprises an at least partly hollow dielectric resonance element which is pinched between the base and the cover of the housing of the dielectric resonator. The resonant frequency of the TM-mode resonator depends on the ratio of the outer diameter of the dielectric resonance element and the inner diameter of the resonator housing, but is independent of the height of the dielectric resonance element and the housing. Such dielectric resonators are waveguide resonators. Due to the presence of only one conductor, waveguide resonators do not support the transversal electromagnetic (TEM) mode but mainly the transversal electric (TE) and transversal magnetic (TM) modes. Further, they have a distinct cut-off frequency above which electromagnetic energy will propagate and below which it is attenuated. The cut-off frequency is determined by the cross-sectional dimensions. For example, a waveguide having a rectangular cross-section must have a width at least greater than one-half of the free space wavelength for propagation to occur at a particular frequency. Waveguides can support an infinite number of modes, each having its own cut-off frequency.

[0006] One particular type of resonator distinctly different from the above waveguide resonators and regularly used to build microwave filters is known as coaxial resonator. This resonator structure is short-circuited at one end and open circuited at the other end, i.e. comprises a housing defining a cavity and having a longitudinal axis, and a coaxial inner conductor electrically connected to the housing at only one end. The housing comprises a base or lower end wall, from which the inner conductor extends upwardly, and a sidewall extending upwardly from the base, and in a certain distance above the open end of the inner conductor, the housing is enclosed by a cover or upper end wall so that a gap exists between one end of the inner conductor and the inner surface of the cover. Such coaxial resonators are also referred to as combline resonators, and can essentially be regarded as a section of coaxial transmission line that is short-circuited at one end and capacitively loaded (open) at the other end. Microwave energy may be cou-

pled into the cavity by a magnetic loop antenna located near the inner conductor at the short-circuited end of the transmission line. The free space between the top of the inner conductor and the cover is referred to as the capacitive gap. In general, the length of the inner conductor is greater than the width of the capacitive gap.

[0007] In contrast to waveguide resonators, coaxial resonators belong to the category of TEM-transmission line resonators supporting the TEM-mode which has zero cut-off frequency. They exhibit an entirely different distribution of the electromagnetic field. A coaxial resonator has a height of lower than $\lambda/4$ - typically $\lambda/8$ - where λ is the wavelength corresponding to the center of the pass-band. The short (electrical connection between inner conductor and base plate) at the bottom of the resonator is transformed to an inductance at the top of the resonator, which together with the capacitive gap at the top of the resonator create the fundamental resonance. Since the TE- and TM-modes of the resonator exhibit a strong dependency on the resonator diameters, the outer diameter of the resonator should be kept small - typically much smaller than $\lambda/2$ of the fundamental pass-band frequency - if the TE- and TM-modes are to be kept at higher frequencies than the TEM-mode. The ratio of the outer diameter of the resonator to the outer diameter of the inner conductor should lie around 3.6 to guarantee a high quality factor of the resonator, since at this ratio the damping constant of the corresponding coaxial line is minimal.

[0008] The resonant frequency of a coaxial resonator is determined by various factors, predominantly by the length of the cavity, the length of the inner conductor and the size of the capacitive gap. To render a coaxial resonator adjustable, a hole may be provided in the cover above the inner conductor, in which hole a tuning screw is placed. Adjusting the tuning screw one can change the capacitive gap and thus control the resonant frequency. In some cases, the inner conductor may be provided as a partly hollow component and the tuning screw may be arranged to at least partly penetrate this inner conductor. Such a resonator structure is referred to as re-entrant combline resonator. The tuning screw may also be disposed in holes provided in the sidewalls or the base of the housing.

[0009] In order for a microwave filter to yield the desired filter characteristics, it is generally essential that the distinct resonators coupled together to form the filter have a predetermined resonant frequency and band width or pass-band. As the resonant frequency is largely determined by the size and shape of the resonator structure, the dimensions of a particular resonator have to be thoroughly calculated and the production process has to be carefully controlled. Further, a general problem of microwave filters is that they have to be as small and lightweight as possible while simultaneously retaining the desired filter characteristics. This is particularly true for filters utilized in modern mobile communications systems such as base station filters.

[0010] In the state of the art, such as in exemplary doc-

ument US 6,686,815, coaxial resonators are known which are dielectrically loaded by means of a sleeve-shaped dielectric element disposed around the inner conductor along a part of the length or the entire length of the inner conductor. By providing such a dielectric sleeve, which has a length smaller than or equal to the length of the inner conductor, the resonant frequency of the coaxial resonator is changed in such a way that the distance between the inner conductor and the sidewall can be reduced, while achieving the same resonant frequency as for the resonator with a larger distance between the inner conductor and the sidewall and without the dielectric sleeve. Further, the electrical length of the inner conductor is changed. In this way, for a coaxial resonator having desired characteristics, the physical dimensions of the housing as well as of the inner conductor and thus the overall size of the coaxial resonator can be reduced. Microwave filters comprising such dielectrically loaded coaxial resonators are for example regularly used in base stations.

[0011] However, while these coaxial resonators are lightweight and smaller as compared to conventional coaxial resonators, they are relatively costly because the dielectric element, and thus an additional component, has to be secured to the base or the inner conductor by suitable fastening means. Further, like any coaxial resonator, frequency stability is a problem, in particular in high power applications. An insufficient frequency stability or detuning of the prior art coaxial resonators may arise from heat generated during operation of the resonators. Like any kind of resonator structure, coaxial resonators are subject to thermal expansion and contraction of their housing and other components such as e.g. the inner conductor, which potentially lead to a change in resonant frequency as the temperature varies. In such cases, the power capability of filters including such coaxial resonators is reduced. Further, a high temperature induced expansion leads to high mechanical stress which significantly reduces the service life of the filters. For microwave filters, frequency stability is of paramount importance because it ensures that the filters band pass requirements can be maintained without using additional bandwidth. Eventually one can design the filter with a larger bandwidth without violating the band stop requirements, which decreases the insertion loss.

[0012] It is an object of the present invention to provide a dielectrically loaded coaxial resonator which exhibits high frequency stability, and which can be constructed in a cost-efficient way and which has a high service life. Further, it is an object of the present invention to provide a microwave filter comprising a plurality of coupled resonators including at least one dielectrically loaded coaxial resonator, which microwave filter exhibits the above characteristics.

[0013] This object is achieved by a coaxial resonator as defined in claim 1. Preferred embodiments of the invention are set out in the dependent claims.

[0014] The coaxial resonator of the present invention

comprises a housing defining a cavity and having a base or lower end wall, a sidewall extending upwardly from the lower end wall, and an upper cover or upper end wall. The housing is constructed such that at least its inner surface, i.e. the surface defining the cavity, is made from a conductive material. Thus, the housing itself is made from a conductive material such as metal, or the inner surface of the housing is provided with a layer of conductive material such as metal. As usual, the coaxial resonator comprises an inner conductor disposed within the housing. The inner conductor is arranged to extend upwardly from the lower end wall along the longitudinal axis of the housing, and the inner conductor is electrically connected to the lower end wall. In the present specification, the longitudinal (or axial) direction of the housing or of the inner conductor is defined as usual as the direction along which the inner conductor extends upwardly from the base. The width of the capacitive gap formed between the upper end of the inner conductor and the upper end wall is preferably smaller than the length of the inner conductor, and usually the width of the capacitive gap will be much smaller than the length of the inner conductor. Further, a hollow dielectric element is provided which surrounds the inner conductor along its entire length, i.e. the dielectric element includes an interior channel or cavity in which the inner conductor extends such that the dielectric element is disposed between the sidewall of the housing and the entire lateral outer surface of the inner conductor.

[0015] The present invention is based on the finding that the length of the hollow dielectric element may exceed the length of the inner conductor without deteriorating the electromagnetic characteristics of the coaxial resonator. Thus, the length of the hollow dielectric element is chosen in such a way that it can be mechanically secured within the cavity by clamping between the lower end wall and the upper end wall, i.e. the length of the hollow dielectric element is equal to the distance between opposing portions of the lower end wall and the upper end wall. With other words, the lower end wall exerts an upwardly directed force on the lower end of the hollow dielectric element and the upper end wall exerts a downwardly directed force on the upper end of the hollow dielectric element to thereby support the hollow dielectric element in its place within the cavity.

[0016] In this way, no expensive fastening means for the dielectric element are necessary, but it can be simply fixed by arranging it around the inner conductor and by subsequently closing the housing by securing the lower end wall and/or the upper end wall to the sidewall. This provides for a particularly cost-efficient production of the coaxial resonator. Furthermore, due to the additional contact between the housing and the dielectric element, a better heat removal is achieved, leading to enhanced frequency stability and a better service life performance. To maximize the transfer of heat between the housing and the dielectric element, one or more of the surfaces of the dielectric element contacting the housing may be

covered with a layer of metallic material. The invention provides the further advantage that it is easily possible to replace the hollow dielectric element with a different hollow dielectric element having other dimensions. In this way, a further means for adjusting the resonant frequency of a coaxial resonator is provided.

[0017] In a preferred embodiment, the dielectric element has the form of an elongate sleeve. In particular, the dielectric element may have the form of a hollow cylinder. The latter design is particularly advantageous in case the inner conductor is a cylindrical element. In any case, it is preferred if the cross sectional shape of the interior channel or cavity in the dielectric element is adapted to the cross sectional shape of the inner conductor, which can take any form such as e.g. circular, oval or rectangular. The choice of the wall thickness of the hollow dielectric element depends on the desired electrical and mechanical properties of the coaxial resonator.

[0018] It is further preferred if the dielectric element is made of BaTi_4O_9 , $\text{Ba}_2\text{Ti}_9\text{O}_{20}$, a silicon carbide (SiC) ceramic, barium zinc tantalate, zirconium tin titanate, calcium titanate - neodymium aluminate, calcium titanate - barium tungstate, or lanthanum zinc titanate. Preferably, the relative permittivity ϵ_r of the dielectric element has a value between 30 and 80.

[0019] It is further advantageous if the inside diameter of the hollow dielectric element and the diameter of the inner conductor are equal so that the outer circumference of the inner conductor is in contact with the dielectric element. With other words, in the portion of the interior channel or cavity of the hollow dielectric element in which the inner conductor is disposed, the cross section of the interior channel or cavity is completely filled by the inner conductor. In this way, there is a good thermal contact between the inner conductor and the dielectric element, thereby enhancing heat removal. Further, in case a tuning screw is provided above the upper end of the inner conductor, the field around this tuning screw is reduced, so that fine tuning of the filter is facilitated.

[0020] In a preferred embodiment, the sidewall and the lower end wall are integrally formed in one piece. In this case, the upper end wall is provided as a separate element which is secured to the sidewall by suitable fastening means, such as e.g. by means of screws, clamps, an adhesive or snap-fitting, in order to form the housing. In an alternative preferred embodiment, the sidewall and the upper end wall are integrally formed in one piece. In this case, the lower end wall is a separate component from the sidewall and is secured to the sidewall by suitable fastening means, such as e.g. by means of screws, clamps, an adhesive or snap-fitting, in order to form the housing. In these two embodiments, the number of parts from which the housing is constructed is reduced, thereby facilitating assembly. However, it can also be advantageous if the sidewall is a separate component which is mechanically secured to the upper end wall and the lower end wall by suitable fastening means, such as e.g. by

means of screws, clamps, an adhesive or snap-fitting, in order to form the housing.

[0021] It can further be advantageous if the dielectric element is mechanically attached to the upper end wall and/or the lower end wall. In contrast to the state of the art, such a mechanical attachment does not have to be very strong because the dielectric element is already secured within the cavity by means of clamping.

[0022] In a preferred embodiment, the upper end wall and/or the lower end wall comprise a resilient portion which is adapted to exert a spring force on the dielectric element which constitutes at least a part of the clamping force securing the dielectric element within the cavity. In this way, the dielectric element is even securely held in place by the clamping force if the coaxial resonator changes its dimensions due to a change in temperature.

[0023] In a preferred embodiment, the sidewall, the lower end wall and/or the upper end wall of the coaxial resonator comprise or are made of copper, iron, aluminum, invar, brass, plastic material coated with a layer of conductive material, or a combination of these materials. In general, aluminum is preferred for reasons of weight and costs. In case of the use of aluminum, invar or brass, it is preferred that the respective components are coated with a conductive layer, such as e.g. silver, at least on the side facing the cavity defined by the housing.

[0024] Further, it is preferred that the inner conductor comprises or is made of copper, iron, aluminium, invar, brass, plastic material coated with a layer of conductive material, or a combination of these materials. In general, aluminum is preferred for reasons of weight and costs. In case of the use of aluminum, invar or brass, it is preferred that the inner conductor is coated with a conductive layer, such as e.g. silver.

[0025] In a further preferred embodiment, the inner conductor is formed by plating the inside of the hollow dielectric element with a layer of conductive material along a portion of the length of the hollow dielectric element, i.e. in the upper end region of the hollow dielectric element, its inside is not plated with conductive material to form the capacitive gap.

[0026] The lower end wall and the inner conductor can be provided as separate elements which are fixed together, e.g. by means of screws or bolts, by soldering or brazing, by using a suitable adhesive, or by means of mating threads provided on the base and on the inner conductor. It can be advantageous if the inner conductor is releasably attached to the base. In this way, the inner conductor of a coaxial resonator can be replaced with an inner conductor having other dimensions in order to change, if necessary, the resonant frequency of the resonator. Alternatively, the lower end wall and the inner conductor are advantageously integrally formed in one piece. The latter construction provides for ease of manufacture and ensures high thermal and electric conductivity between the lower end wall and the inner conductor.

[0027] It is further preferred that the lower end wall and/or the inner conductor are formed by milling, die-

casting, cold extrusion or forming from sheet metal. This is particularly advantageous if the base and the inner conductor are integrally formed in one piece. Cold extrusion provides the advantage that the base and/or the inner conductor can be precisely dimensioned while using a low amount of material, and may thus be produced in a particularly cost-efficient manner.

[0028] In a preferred embodiment, at least one of the coaxial resonators of the present invention is part of a microwave filter comprising a plurality of coupled resonators. Thus, the present invention also relates to a microwave filter comprising a plurality of coupled resonators, wherein the plurality of coupled resonators includes one or several of the above defined dielectrically loaded coaxial resonators according to the present invention. In a particularly preferred embodiment, the plurality of coupled resonators only includes coaxial resonators according to the present invention. In any case, the lower end walls and/or upper end walls of two or more of the coaxial resonators of the invention may be integrally formed in one piece. Such a common lower end wall may also integrally include one or more of the inner conductors of the respective coaxial resonators. Further, the sidewalls of two or more of the coaxial resonators of the invention may be integrally formed in one piece. In this way, a microwave filter comprising a plurality of coaxial resonators may be produced in a very cost-efficient manner.

[0029] In the case of a microwave filter comprising a plurality of coupled resonators including at least one of the coaxial resonators of the present invention, it can also be advantageous if the individual coaxial resonators are formed as separate elements which are mechanically connected to form the filter. It has been realized that the filter characteristics are largely governed by the dimensions of the individual resonators, and that the coupling between these resonators is less critical. Thus, a plurality of resonators, each closely meeting particular specifications, may be mechanically coupled together to form a particular filter configuration without impairing the desired filter performance. In this way, a microwave filter with specific filter characteristics may be produced in a very flexible and cost-efficient way.

[0030] In the following, the invention is explained in more detail for preferred embodiments with reference to the figures.

Figure 1 is a schematic cross sectional side view of a dielectrically loaded coaxial resonator.

Figure 2 is a schematic cross sectional side view of a microwave filter comprising four coupled coaxial resonators of Figure 1.

Figure 3 is a schematic cross sectional top view of the microwave filter shown in Figure 2 along line III-III.

[0031] In Figure 1, a dielectrically loaded coaxial res-

onator 1 is shown in cross section which is to be used in a microwave filter comprising a plurality of coupled resonators. The resonator 1 comprises a hollow housing 2 constituted by a plate shaped base or lower end wall 3, a sidewall 4 extending upwardly from the lower end wall 3, and a cover or upper end wall 5 secured to the upper end of the sidewall 4. Thus, the housing 2 encloses and defines a resonator cavity 1a. In the embodiment shown in Figure 1, the sidewall 4 is integrally formed in one piece with the lower end wall 3. The lower end wall 3 and the upper end wall 5 may e.g. have a circular or rectangular shape. Accordingly, the sidewall 4 may have e.g. a cylindrical configuration or may have a rectangular cross section.

[0032] The coaxial resonator 1 further comprises a cylindrical inner conductor 6 centrally connected at its lower end 7 to the lower end wall 3 of the housing 2. In the embodiment of Figure 1, the inner conductor 6 and the lower end wall 3 are integrally formed in one piece, so that the inner conductor 6, the lower end wall 3 and the sidewall 4 are a single component. In alternative embodiments, in which the inner conductor 6 is not formed integrally with the lower end wall 3, the inner conductor 6 may be attached to the lower end wall 3 by means of screws or bolts, by soldering or brazing, by using a suitable adhesive, or by means of mating threads provided on the lower end wall 3 and on the inner conductor 6. The inner conductor 6 extends upwardly from the lower end wall 3 along the longitudinal axis of the housing 2. The inner conductor 6 has a length which is smaller than the length of the housing 2, so that a capacitive gap is formed between the upper end 8 of the inner conductor 6 and the upper end wall 5 of the housing 2.

[0033] While the inner conductor 6 of the coaxial resonator shown in Figure 1 is formed as a solid element, it can also be formed from sheet metal, e.g. by means of cold extrusion, as a hollow component. In this way, the weight and the costs of the resonator 1 can be reduced.

[0034] The coaxial resonator 1 further comprises a tuning screw 9 extending through a hole provided in the upper end wall 5 above the inner conductor 6. The tuning screw 9 can be moved into or out of the coaxial resonator 1 in order to change the capacitive gap between the top 8 of the inner conductor 6 and the upper end wall 5, and to thereby adjust the resonant frequency of the resonator 1.

[0035] The coaxial resonator 1 further includes an elongate hollow, sleeve-shaped dielectric element 10 comprising an interior channel 11 extending along the longitudinal axis of the dielectric element 10. The dielectric element 10 is disposed surrounding the inner conductor 6 such that in every lateral direction, the dielectric element 10 is disposed between the inner conductor 6 and the sidewall 4. The cross sectional diameter of the inner conductor 6 and the cross sectional diameter of the channel 11 of the dielectric element 10 are chosen to be identical, so that the entire side surface of the inner conductor 6 is in intimate contact with the dielectric element

10. The length of the dielectric element 10 is larger than the length of the inner conductor 6 and is chosen to be identical to the height of the cavity 1a in a radially central portion of the cavity 1a surrounding the longitudinal axis of the housing 2. In this way, the dielectric element 10 is firmly secured by clamping between the upper surface 12 of the lower end wall 3 and the lower surface 13 of a central plate-shaped circular portion 14 of the upper end wall 5.

[0036] In order to enhance the clamping force and to accommodate changes in the dimensions of the housing 2, the inner conductor 6 and/or the dielectric element 10, the upper end wall 5 comprises three radial portions. The central portion is the central plate-shaped portion 14 which is in contact with the upper end of the dielectric element 10. The third, outermost annular portion 16 is secured to the upper end of the sidewall 4. Between the outermost portion 16 and the central portion 14, the second portion 15 having an annular shape is disposed. The second portion 15 has a reduced thickness as compared to portions 14 and 16 so as to yield it resilient. In this way, the central portion 14 of the upper end wall 5 is able to move in the longitudinal direction of the housing 2 and to exert a downward force on the upper end of the dielectric element 10 which has a length which exceeds the length of the sidewall 4 so that it protrudes beyond the upper circumferential edge of the sidewall 4. This arrangement provides for the possibility of accommodating temperature induced dimensional changes of resonator components, and for a good thermal contact between the dielectric element 10 and the upper end wall 5 and the lower end wall 3. Thus, the heat generated by the electric currents is efficiently dissipated, so that the current induced rise in temperature of the resonator 1 as well as a corresponding change of the dimensions of the resonator 1 is limited. Thus, the resonator 1 yields excellent frequency stability.

[0037] The lower end wall 3, the inner conductor 6, the sidewall 4 and the upper end wall 5 consist of metal material. The upper end wall 5 is secured by means of its outermost annular portion 16 to the upper circumferential edge of the sidewall 4 such that a good electric connection is established between the upper end wall 5 and the sidewall 4.

[0038] The field in the resonator 1 is excited and extracted by means of suitable coupling means 17a and 17b, respectively, which may e.g. be a coupling loop or an electrical probe. In this regard, it should be noted that, in contrast to the dielectric TM-mode resonators mentioned above, capacitive coupling is possible.

[0039] Figure 2 shows a cross sectional view of a microwave filter 18 comprising four of the dielectrically loaded coaxial resonators 1 shown in Figure 1 which are coupled together in series in a linear arrangement. It should be noted that in general, the coaxial resonators 1 forming a microwave filter will be coupled together in a two-dimensional or a three-dimensional array. In Figure 2, like components are denoted by the same reference numer-

als used in Figure 1. In Figure 3, a cross sectional top view of the microwave filter 18 along line III-III of Figure 2 is shown.

[0040] The field in the filter 18 is excited and extracted by means of suitable coupling means 17a and 17b, respectively, which may e.g. comprise a coupling loop or an electric probe.

[0041] As can be seen in Figures 2 and 3, all lower end walls 3, sidewalls 4 as well as the inner conductors 6 are integrally formed in one piece as a single component 19 which is common to all resonators 1 of the filter 18. While the upper end walls 5 of the four resonators 1 are shown as separate components, they could of course likewise be integrally formed in one piece as a single component which is common to all resonators 1 of the filter 18.

[0042] As can be appreciated from Figures 2 and 3, the individual coaxial resonators 1 are coupled by three coupling windows 20. One of the coupling windows 20 is provided in the common sidewall section 21 between each two adjacent coaxial resonators 1. The sequence of the resonators 1 between the input coupling 17a and the output coupling 17b constitutes the electromagnetic path of the microwave filter 18.

[0043] As shown in Figure 3, the inner conductors 6 have a circular cross sectional shape, the dielectric elements 10 are hollow cylinders, and the housing 2 has a rectangular cross sectional shape. However, these elements may also have other cross sectional shapes.

Claims

1. A coaxial resonator comprising:

- a conductive housing (2) defining a cavity (1a) and having a lower end wall (3), a sidewall (4) extending upwardly from the lower end wall (3), and an upper end wall (5),
- an inner conductor (6) disposed within the housing (2) and extending upwardly from the lower end wall (3) and electrically connected to the lower end wall (3), and
- a hollow dielectric element (10) surrounding the inner conductor (6) along its entire length,

characterized in that the hollow dielectric element (10) is mechanically secured within the cavity (1a) by clamping between the lower end wall (3) and the upper end wall (5).

2. The coaxial resonator according to claim 1, wherein the hollow dielectric element (10) has the form of an elongate sleeve.
3. The coaxial resonator according to claim 2, wherein the hollow dielectric element (10) has the form of a hollow cylinder.

4. The coaxial resonator according to any of the preceding claims, wherein the hollow dielectric element (10) is made of BaTi_4O_9 , $\text{Ba}_2\text{Ti}_9\text{O}_{20}$, a silicon carbide (SiC) ceramic, barium zinc tantalate, zirconium tin titanate, calcium titanate - neodymium aluminate, calcium titanate - barium tungstate, or lanthanum zinc titanate.
5. The coaxial resonator according to any of the preceding claims, wherein the inside diameter of the hollow dielectric element (10) and the outer diameter of the inner conductor (6) are equal so that the outer circumference of the inner conductor (6) is in contact with the hollow dielectric element (10).
6. The coaxial resonator according to any of the preceding claims, wherein the sidewall (4) and the lower end wall (3) are integrally formed in one piece.
7. The coaxial resonator according to any of claims 1 to 5, wherein the sidewall (4) and the upper end wall (5) are integrally formed in one piece.
8. The coaxial resonator according to any of claims 1 to 5, wherein the sidewall (4) is a separate component which is mechanically secured to the upper end wall (5) and the lower end wall (3) by suitable fastening means.
9. The coaxial resonator according to any of the preceding claims, wherein the hollow dielectric element (10) is mechanically attached to the upper end wall (5) and/or the lower end wall (3).
10. The coaxial resonator according to any of the preceding claims, wherein the upper end wall (5) and/or the lower end wall (3) comprise a resilient portion (15) which is adapted to exert a spring force on the hollow dielectric element (10) which constitutes at least a part of the clamping force securing the hollow dielectric element (10) within the cavity (1a).
11. The coaxial resonator according to any of the preceding claims, wherein the sidewall (4), the lower end wall (3) and/or the upper end wall (5) comprise copper, iron, aluminum, invar, brass or a plastic material coated with a layer of conductive material.
12. The coaxial resonator according to any of the preceding claims, wherein the inner conductor (6) comprises copper, iron, aluminum, invar, brass or a plastic material coated with a layer of conductive material.
13. The coaxial resonator according to any of the preceding claims, wherein the inner conductor (6) is formed by plating, along a portion of the length of the hollow dielectric element (10), the inside of the

hollow dielectric element (10) with a layer of conductive material.

14. The coaxial resonator according to any of the preceding claims, wherein the lower end wall (3) and the inner conductor (6) are separate elements which are mechanically secured to each other. 5
15. The coaxial resonator according to any of claims 1 to 13, wherein the lower end wall (3) and the inner conductor (6) are integrally formed in one piece. 10
16. The coaxial resonator according to claim 15, the lower end wall (3) and/or the inner conductor (6) are formed by milling, die-casting, cold extrusion or forming from sheet metal. 15
17. A microwave filter comprising a plurality of coupled resonators (1), wherein the plurality of coupled resonators (1) includes at least one coaxial resonator (1) according to any of claims 1 to 16. 20
18. The microwave filter according to claim 17, wherein the plurality of coupled resonators (1) only includes coaxial resonators (1) according to any of claims 1 to 16. 25

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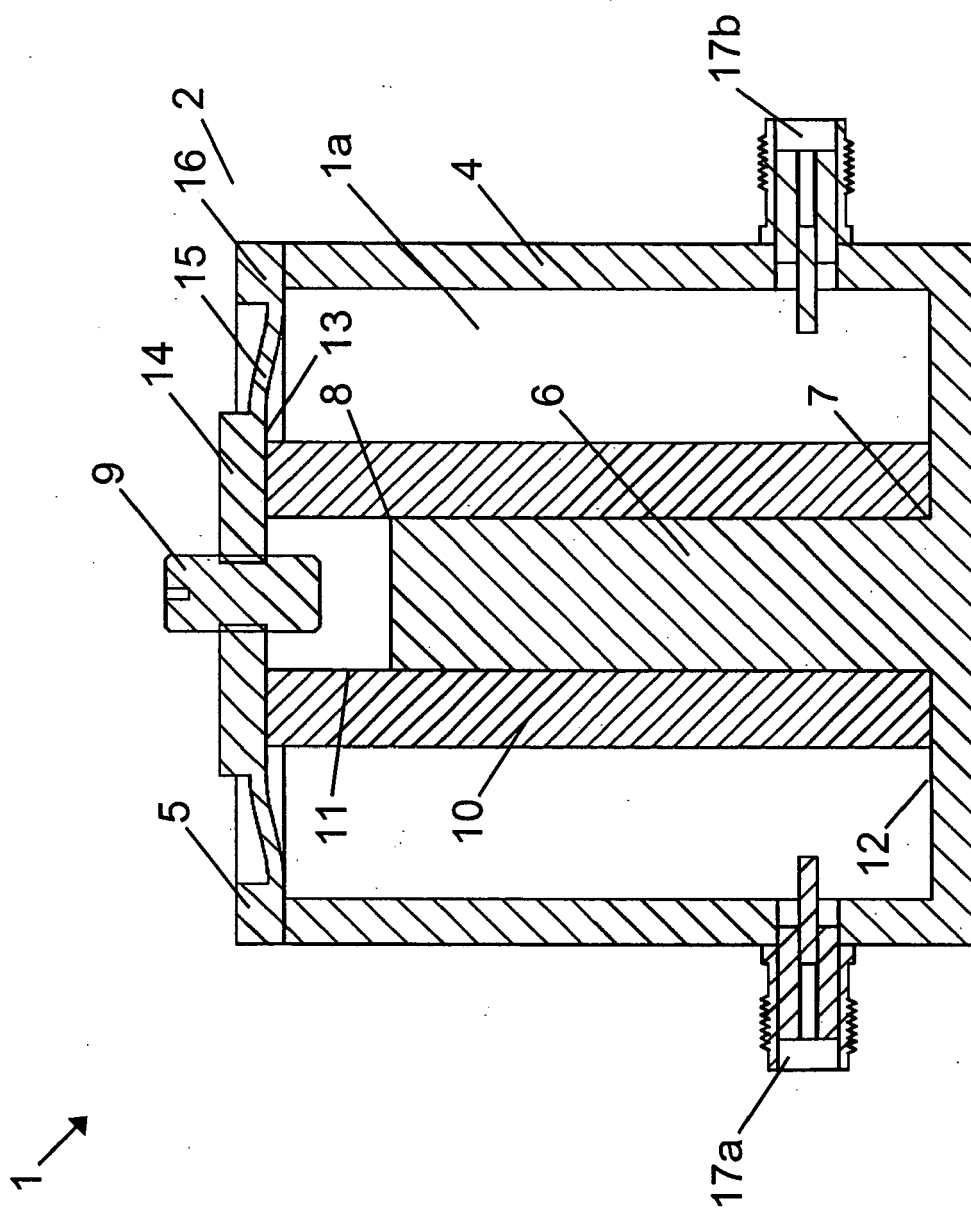


Fig. 1

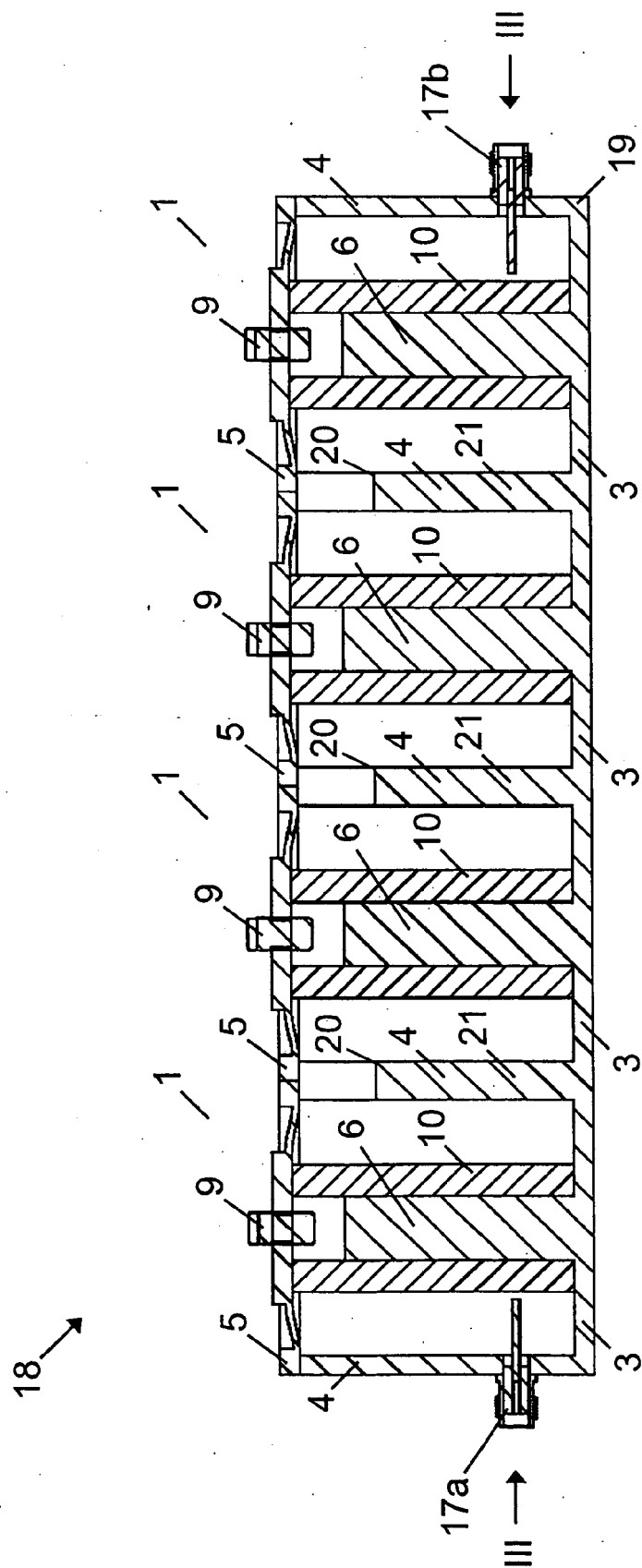


Fig. 2

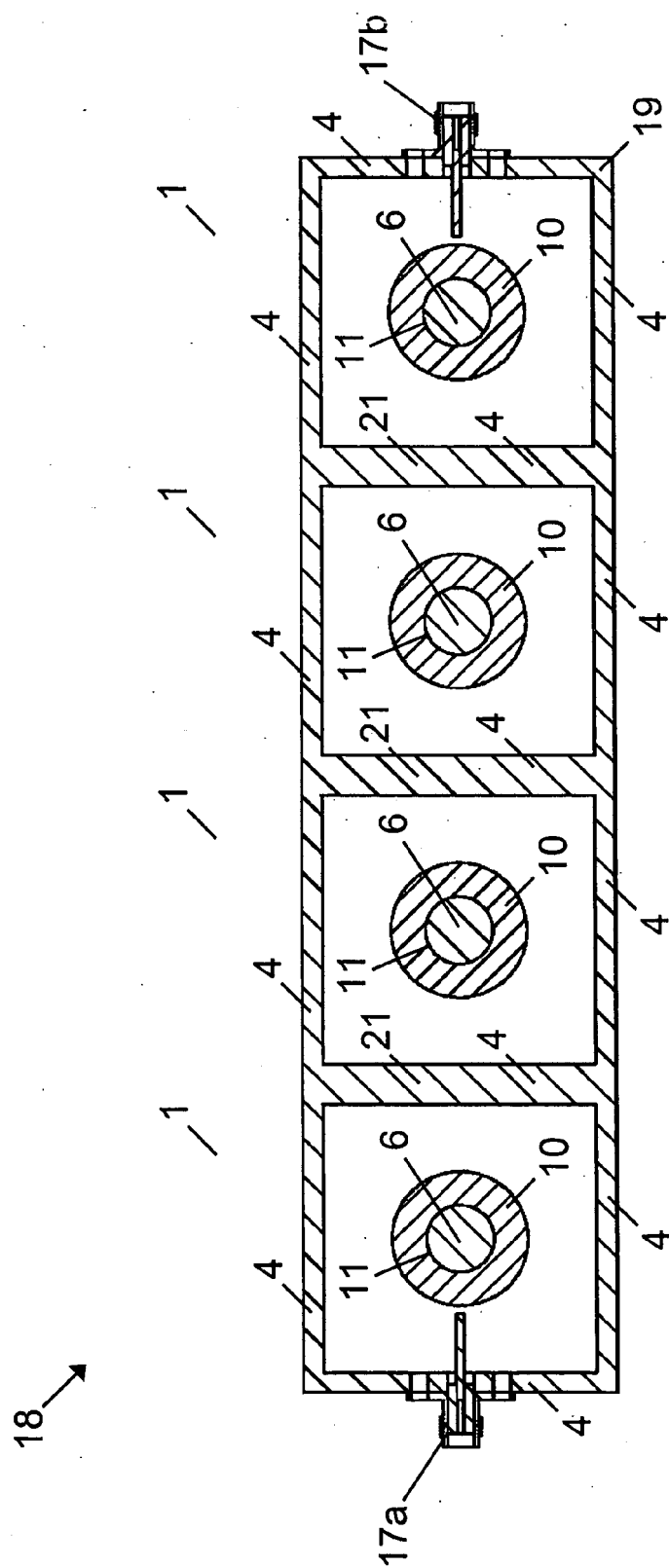


Fig. 3



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EUROPEAN SEARCH REPORT

Application Number
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Place of search The Hague		Date of completion of the search 17 January 2006	Examiner Pastor Jiménez, J-V
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