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(54) **Plastic combine filter with metal post to increase heat dissipation**

(57) The present invention relates to a coaxial resonator (1) comprising a housing (2) defining a cavity (1a) and having a base (3), a sidewall (4) extending upwardly from the base (3), and an upper cover plate (5). The sidewall (4) is formed from a plastic material (10) coated on

its inside surface with a layer (11) of conductive material. An inner conductor (6) extends upwardly from the base (3) and is electrically connected to the base (3). The base (3) and the inner conductor (6) are formed from metal material.

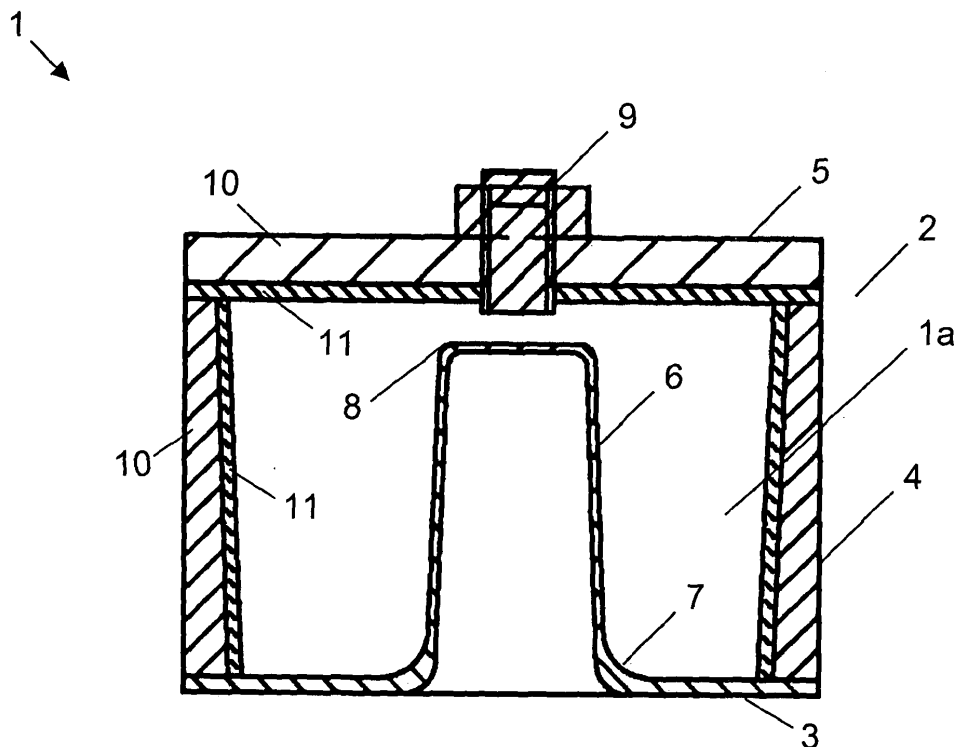


Fig. 1

Description

[0001] The present invention relates to a coaxial resonator with a sidewall formed from a plastic material coated with a layer of conductive material, 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 stations 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] One particular type of resonator 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, 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 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 coupled 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.

[0006] The resonant frequency of a coaxial resonator is determined by various factors such as 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.

[0007] 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.

[0008] For this reason, it is known to construct microwave filters from a unitary metallic body including a plu-

ality of recesses forming the resonant sections. A metallic cover plate is secured to the body to close the recesses. Typically, the body is formed by die-casting or by milling from a solid piece of metal. Such microwave filters are relatively expensive to manufacture, and for every filter, large amounts of material are required. 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.

[0009] One solution to overcome the above problems is to construct the filter and its resonant sections from a plastic material which is coated on its interior surface with a conductive material in order to provide the closed or substantially closed conducting surface.

[0010] An example of one such type of microwave filter is described in US 5,329,687. This microwave filter consists of a plurality of coupled coaxial resonators. The side-walls and the bases together with the inner conductors of all coaxial resonators are integrally constructed in one piece by a framework formed from a moldable material, such as plastic, which is plated with a conductive layer. The framework may be produced in a cost-efficient manner by injection molding. The cover of the housing may likewise be formed from a moldable material which is then plated with a conductive layer, or may be formed from a suitable conductive material, such as aluminum. The cover may be secured to the remainder of the housing by snap-fitting.

[0011] A similar plastic microwave filter consisting of a plurality of coupled coaxial resonators is known from US 3,896,545.

[0012] However, while these filters are lightweight and less expensive to produce as compared to conventional microwave filters produced from a solid block of metal and comprising a plurality of coupled resonators including at least one coaxial resonator, they tend to lack frequency stability in use and in particular in high power applications. 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.

[0013] The insufficient frequency stability or detuning of the above prior art filters is caused by heat generated during operation of the filters. 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. Generally, the amount of expansion and contraction of a dimension depends on its size, the change in temperature and the coefficient of thermal expansion (CTE) of the material and is described by the following equation:

$$\Delta l = (1 + \alpha \cdot \Delta T) \cdot l,$$

where α is the CTE of the material, ΔT the change in temperature and l the length of the dimension. For example, it has been shown that any resonator structure built out of only one material undergoes a shift in resonant frequency described by the following equation:

$$f(\Delta T) = f_0 \frac{1}{(1 + \alpha \cdot \Delta T)}.$$

[0014] With the exception of specifically developed particular high-cost compound materials consisting of a mixture of plastic material and glass fibers, due to which these compound materials have a high weight and are more difficult to manufacture by injection-molding, the plastic materials plated with a conductive layer and used to build the above plastic filters consisting of coupled coaxial resonators have a higher coefficient of thermal expansion than aluminum or other well known materials for this type of filter. In any case, plastic materials coated with a conductive layer exhibit a much lower thermal conductivity as compared to the metallic materials alternatively utilized to build microwave filters. Thus, in use, and especially in high power applications, the heat generated by the loss of the filter in the inner conductive layer cannot be dissipated efficiently (because of the low thermal conductivity), and gives rise to a substantial increase of the temperature of the conductive layer and eventually the entire housing and inner conductor of the individual coaxial resonators. The increase of temperature of the conductive layer causes extra losses which further heat up the filter. For these reasons, microwave filters constructed from plastic material coated with a conductive layer regularly exhibit insufficient filter performance with significant detuning of the filter caused by a high temperature increase during operation of the filter and thus high thermal expansion. Therefore, the power capability of such filters is reduced. Further, the high temperature induced expansion leads to high mechanical stress which significantly reduces the service life of the filters.

[0015] It is an object of the present invention to provide a lightweight high performance coaxial resonator which exhibits high frequency stability, 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 coaxial resonator, which microwave filter exhibits the above characteristics.

[0016] 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.

[0017] The coaxial resonator of the present invention

comprises a housing defining a cavity and having a base, a sidewall extending upwardly from the base, and an upper cover. On all surfaces defining the cavity, a conductive material is disposed (i.e. the walls are made of conductive material or are plated with a layer of conductive material). A major portion of the housing, which portion at least includes the sidewall of the housing, is made from a plastic material coated at least on its inside surface, i.e. the surface forming the boundary of the cavity, with a layer of conductive material such as e.g. silver. An inner conductor extends upwardly from the base and is electrically connected to the base. According to the present invention, the base and the inner conductor are made from metal or metal material, i.e. they comprise one or more different metals or metal materials and do not comprise plastic material.

[0018] The invention is based on the finding that the base and the inner conductor are those parts of the coaxial resonator at which the highest current densities occur and at which accordingly the largest amounts of heat are generated during use of the resonator. Thus, the construction of the base and the inner conductor of metal material allows for a very efficient dissipation of heat generated during use of the coaxial resonator. At the same time, the arrangement, according to which the main part of the housing of the resonator including the sidewall is made of plastic material plated with a conductive layer, provides the advantage of low weight and low-cost production, e.g. utilizing injection molding. The coaxial resonator according to the present invention combines the latter advantages with a high frequency stability even during high power applications. One or more of such coaxial resonators may advantageously be utilized to form a microwave filter including a plurality of coupled resonators. In this way, the advantages of the above prior art plastic microwave filters are essentially retained while the performance of the filters for high power applications is substantially increased, with the temperature induced frequency shift or detuning and the losses being reduced. Further, due to a lower degree of expansion mechanical stress is minimized. The weight and size of the coaxial resonators as well as of microwave filters utilizing these coaxial resonators can be reduced by the possibility of using thinner walls. For example, when molding sidewalls from plastic, the wall thickness can be made substantially lower, e.g. lower than 3 mm, as compared to sidewalls constructed from aluminum, which require wall thicknesses of about 5 mm. The plastic components of the coaxial resonator can advantageously be manufactured by injection molding. In particular, it is advantageously possible to use pure plastic materials in order to facilitate injection molding.

[0019] In a preferred embodiment, the base of the coaxial resonator comprises or is made of copper, aluminum, iron, steel, invar or brass, 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, steel or brass, it is preferred that the base is coated with

a conductive layer, such as e.g. silver, at least on the side facing the cavity defined by the housing.

[0020] Further, it is preferred that the inner conductor comprises or is made of copper, aluminium, iron, steel, invar or brass, 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, steel or brass, it is preferred that the inner conductor is coated with a conductive layer, such as e.g. silver.

[0021] In general, preferred metals or metal materials for the construction of the base and the inner conductor have a thermal conductivity of at least 10 W/(m K), preferably at least 200 W/(m K) and most preferably at least 350 W/(m K) at 23 °C. Further, it is preferred if the coefficient of thermal expansion of these metals or metal materials is lower than $25 \times 10^{-6} \text{ K}^{-1}$ and preferably lower than $19 \times 10^{-6} \text{ K}^{-1}$ at this temperature.

[0022] The base 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 base 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 base and the inner conductor.

[0023] It is further preferred that the base and/or the inner conductor are formed by milling, die-casting, cold extrusion, deep drawing or forming from thin metal. This is particularly advantageous if the base and the inner conductor are integrally formed in one piece. Cold extrusion and deep drawing provide 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.

[0024] In a preferred embodiment, the cover, similar to the sidewall, is made from a plastic material coated with a conductive layer such as e.g. silver. However, in order to further increase heat removal and possibly to save costs, it is also possible that the cover is formed from metal material.

[0025] In a further preferred embodiment, the sidewall is attached to the base by means of screws, clamps, an adhesive or snap-fitting. A releasable connection between the base and the sidewall provides the advantage that the sidewall and/or the base and/or the inner conductor may be replaced with a differently dimensioned component in order to change the resonant frequency of the coaxial resonator.

[0026] 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 reso-

nators. 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 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 bases of two or more of the coaxial resonators of the invention may be integrally formed in one piece. Such a common base 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. In case several or all of the coaxial resonators of the microwave filter comprise a common base component integrally formed in one piece and/or a common sidewall component integrally formed in one piece, the connection between these components may be adapted such that it is possible to replace one or both of these components with a differently dimensioned component in order to change the filter characteristics.

[0027] 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 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.

[0028] 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 view of a coaxial resonator.

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

Figure 3 is a schematic perspective view of the microwave filter shown in Figure 2, wherein the cover has been removed.

[0029] In Figure 1, a coaxial resonator 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 3, a sidewall 4 extending upwardly

from the base 3, and a plate shaped cover 5 secured to the upper end of the sidewall 4. Thus, the housing 2 encloses and defines a resonator cavity 1a. The base 3 and the cover 5 may have, e.g., a circular or rectangular shape. Accordingly, the sidewall 4 may have a cylindrical configuration or may have a rectangular cross section.

[0030] The coaxial resonator 1 further comprises a cylindrical inner conductor 6 centrally connected at its lower end 7 to the base 3 of the housing 2. In the embodiment of Figure 1, the inner conductor 6 and the base 3 are integrally formed in one piece. In alternative embodiments, in which the inner conductor 6 is not formed integrally with the base 3, the inner conductor 6 may be attached to the base 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 base 3 and on the inner conductor 6. The inner conductor 6 extends upwardly from the base 3 along the longitudinal axis of the housing 2. The inner conductor 6 has a length which is lower 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 cover 5 of the housing 2.

[0031] While the base 3 and the inner conductor 6 may be formed as a solid element, in the embodiment shown in Figure 1, the base 3 and the inner conductor 6 are formed from sheet metal, e.g. by means of cold extrusion. Thus, the inner conductor 6 is a hollow component. In this way, the weight and the costs of the resonator 1 are reduced.

[0032] The coaxial resonator 1 further comprises a tuning screw 9 extending through a hole provided in the cover 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 cover 5, and to thereby adjust the resonant frequency of the resonator 1.

[0033] The sidewall 4 consists of plastic material 10 which is provided on its inside surface with a conductive coating in the form of a layer 11 of metal material. In the same way, the cover 5 also consists of plastic material 10 having a conductive coating in the form of a layer 11 of metal material. In the embodiment of Figure 1, the conductive layer 11 is provided only on the surface of the cover 5 which is to be disposed in facing relationship with the resonator cavity 1a. However, it is likewise possible that the conductive layer 11 is also disposed on the edges and/or the other surface of the cover 11. Likewise, the conductive layer 11 may also be disposed on surfaces of the sidewall 4 other than the inside surface. While the arrangement shown in Figure 1 is preferred for reasons of weight and costs, it is also possible that the cover 5 is made from metal material. It should be noted, that in Figure 1 the thickness of the layers 11 has been exaggerated for the purpose of illustration.

[0034] The base 3 and the inner conductor 6 consist of metal material. The base 3 is secured to the lower circumferential edge of the sidewall 4 such that a good electric connection is established between the base 3

and the conductive layer 11 on the inside surface of the sidewall 4.

[0035] The field in the resonator 1 is excited by an external circuit (not shown) through suitable coupling means (not shown), which may e.g. comprise an aperture or a coupling loop and radiate a wave into the resonator cavity. In use, the highest current densities occur in the region of the base 3 and the inner conductor 6. Due to the fact that these elements are formed from metal material, the heat generated by the electric currents is efficiently dissipated. Therefore, 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. At the same time, the weight of the resonator 1 is kept low, because the sidewall 4 and the cover 5, i.e. the major portion of the housing 2, essentially consist of plastic material 10.

[0036] Figure 2 shows a cross sectional view of a microwave filter 12 comprising four coaxial resonators 1 of the type 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 array. In Figure 2, like components are denoted by the same reference numerals used in Figure 1. Thus, each coaxial resonator 1 comprises a hollow housing 2 enclosing and defining a resonator cavity 1a and constituted by a plate shaped base 3, a sidewall 4 extending upwardly from the base 3, and a plate shaped cover 5 secured to the upper end of the sidewall 4. The base 3 and the inner conductor 6 are made from metal material, and the sidewall 4 as well as the cover 5 are made from plastic material coated with a conductive layer. In Figure 3, a perspective view of the microwave filter 12 is shown with the covers 5 of the coaxial resonators 1 removed. It should be noted that in Figures 2 and 3 the conductive layers 11 are not shown for the sake of simplicity.

[0037] The field in the filter 12 is excited and extracted by means of suitable coupling means 13a and 13b, respectively, which may e.g. comprise an aperture or a coupling loop.

[0038] As can be seen in Figures 2 and 3, all bases 3 as well as the inner conductors 6 are integrally formed in one piece as a single component 14 which is common to all resonators 1 of the filter 12. In the same way, all covers 5 are integrally formed in one piece as a single component 15 which is common to all resonators 1 of the filter 12. Finally, all sidewalls 4 are integrally formed in one piece as a single component 16 which is common to all resonators 1 of the filter 12. Thus, the filter 12 only comprises three major components 14, 15, 16 which are mechanically secured to each other.

[0039] As described in detail above with reference to Figure 1, the base component 14 consist of metal material and is secured to the lower edges of the sidewall component 16. The cover component 15 and the sidewall component 16 consists of plastic material 10 which is

provided at least on the surface facing the resonator cavities 1a with a conductive coating in the form of a layer of metal material (not shown in Figures 2 and 3).

[0040] As can be appreciated from Figures 2 and 3, the individual coaxial resonators 1 are coupled by three coupling windows 17. One of the coupling windows 17 is provided in the common sidewall section 18 between each two adjacent coaxial resonators 1. The sequence of the resonators 1 between the input coupling 13a and the output coupling 13b constitutes the electromagnetic path of the microwave filter 12.

[0041] In addition to the tuning screws 9 extending through holes provided in the common cover component 15 above each of the inner conductors 6, for each of the coupling windows 17, a respective tuning screw 19 is provided which is arranged to extend through a hole in the common cover component 15 into the respective window 17. By moving the tuning screws 19 into or out of the windows 17, the coupling strength between adjacent coaxial resonators 1 can be adjusted.

Claims

1. A coaxial resonator comprising:

- a housing (2) defining a cavity (1a) and having a base (3), a sidewall (4) extending upwardly from the base (3), and an upper cover (5), wherein the sidewall (4) is formed from a plastic material (10) coated on its inside surface with a layer (11) of conductive material, and
- an inner conductor (6) extending upwardly from the base (3) and electrically connected to the base (3),

characterized in that the base (3) and the inner conductor (6) are formed from metal material.

2. The coaxial resonator according to claim 1, wherein the base (3) comprises copper, iron, steel, aluminum, invar or brass.
3. The coaxial resonator according to claim 1 or 2, wherein the inner conductor (6) comprises copper, iron, steel, aluminum, invar or brass.
4. The coaxial resonator according to any of the preceding claims, wherein the base (3) and the inner conductor (6) are separate elements which are mechanically secured to each other.
5. The coaxial resonator according to any of claims 1 to 3, wherein the base (3) and the inner conductor (6) are integrally formed in one piece.
6. The coaxial resonator according to any of the preceding claims, wherein the base (3) and/or the inner

conductor (6) are formed by milling, die-casting, cold extrusion or forming from sheet metal.

7. The coaxial resonator according to any of the preceding claims, wherein the cover plate (5) is made from a plastic material (10) coated with a conductive layer (11). 5
8. The coaxial resonator according to any of claims 1 to 6, wherein the cover plate (5) is formed from metal material. 10
9. The coaxial resonator according to any of the preceding claims, wherein the sidewall (4) is secured to the base (3) by means of screws, clamps, an adhesive or snap-fitting. 15
10. A microwave filter comprising a plurality of coupled resonators, wherein the plurality of coupled resonators includes at least one coaxial resonator (1) according to any of claims 1 to 9. 20
11. The microwave filter according to claim 10, wherein the plurality of coupled resonators only includes coaxial resonators (1) according to any of claims 1 to 9. 25

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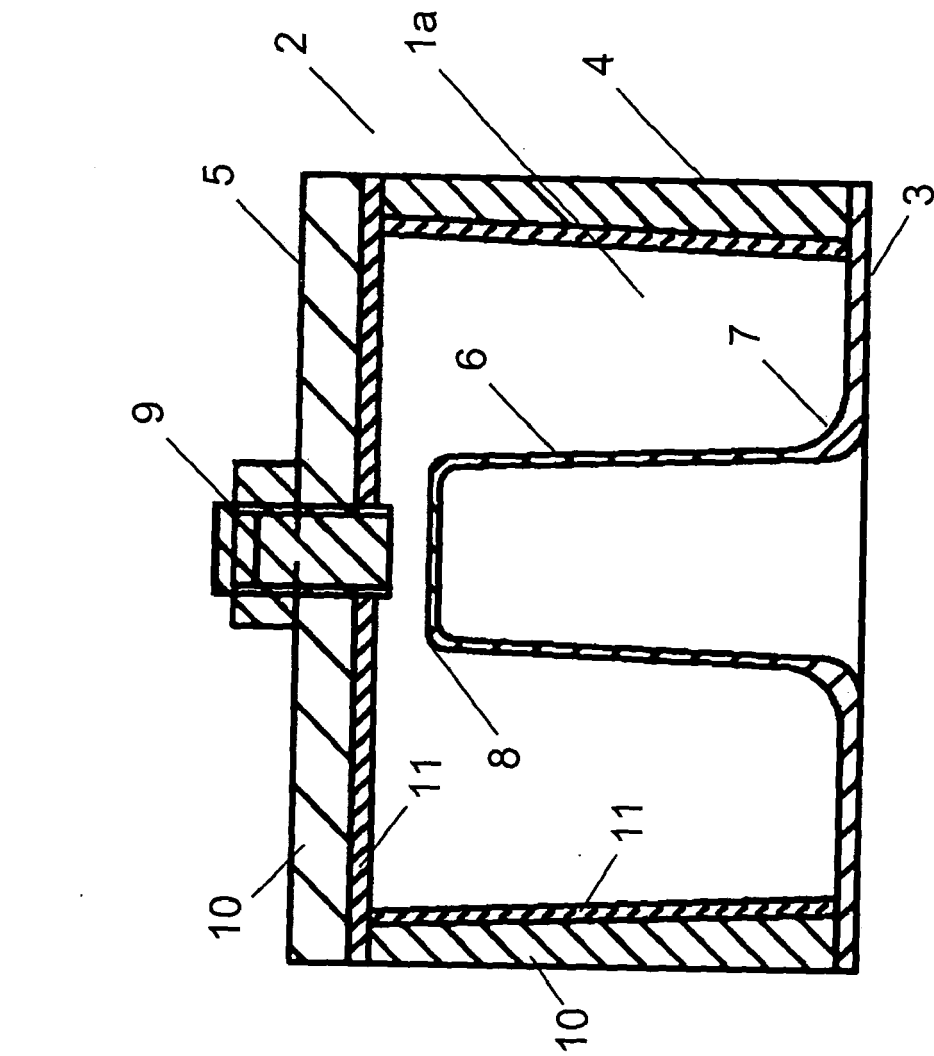


Fig. 1

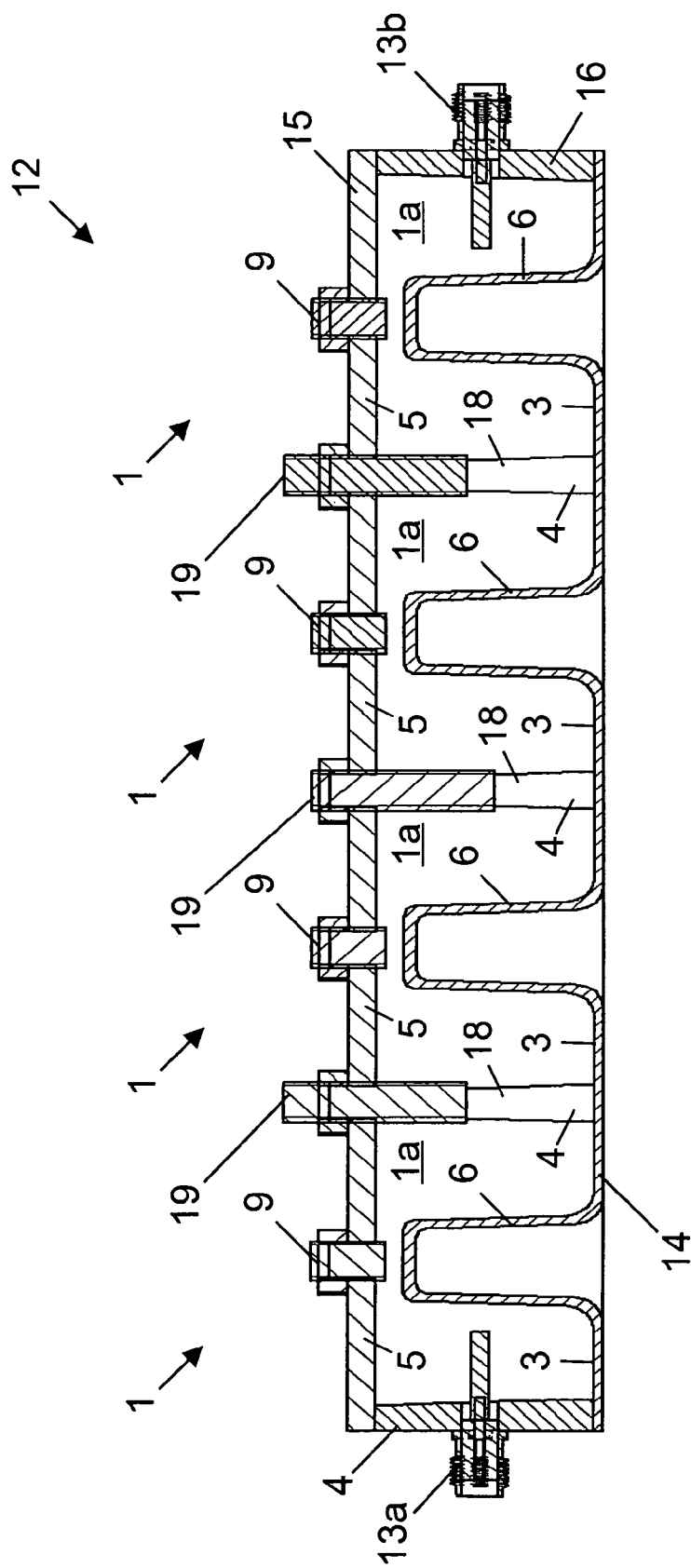


Fig. 2

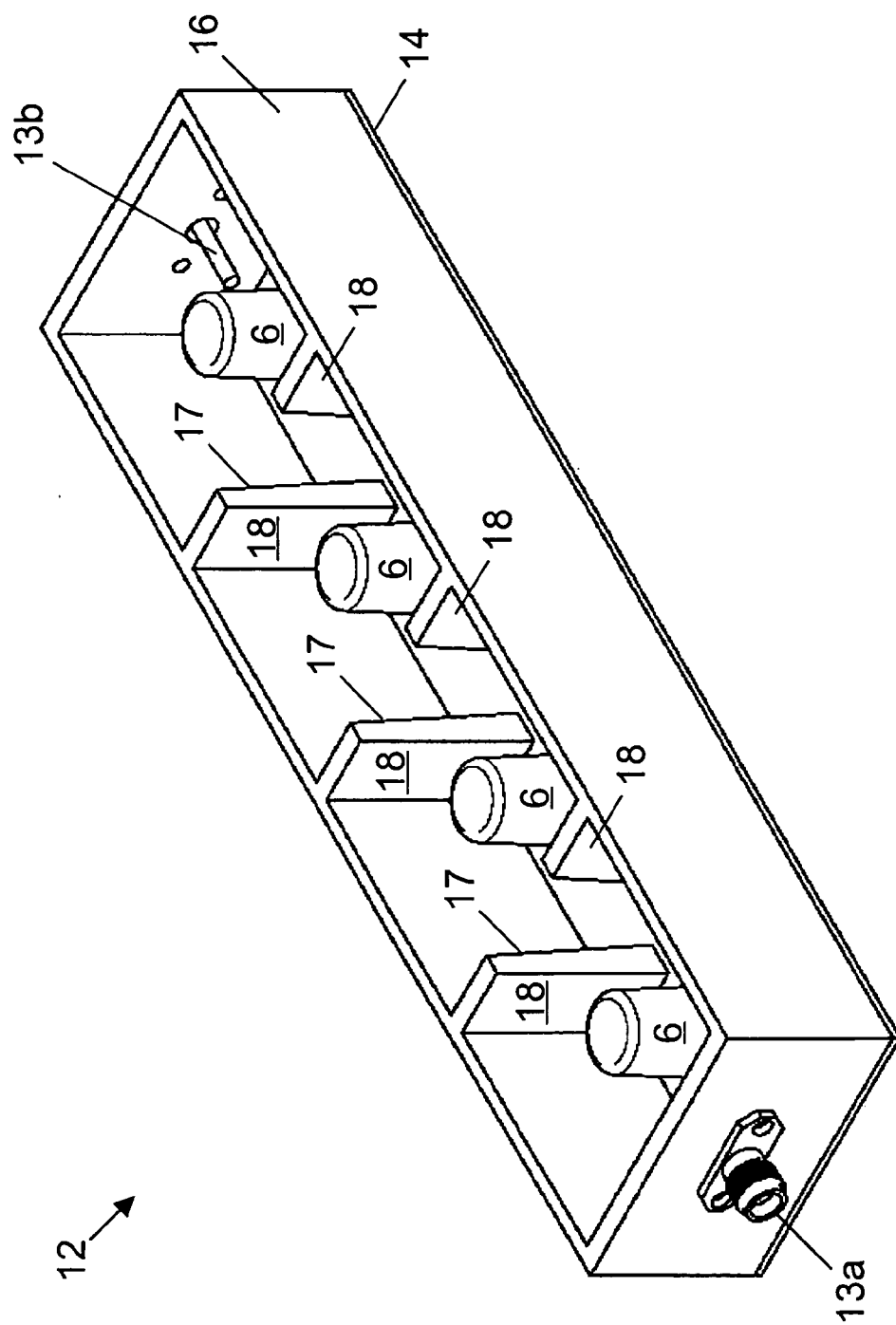


Fig. 3



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 01 5764

DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 2 December 2005	Examiner Pastor Jiménez, J-V
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 05 01 5764

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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