PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01P 7/04

A2

(11) International Publication Number: WO 99/30383

(43) International Publication Date: 17 June 1999 (17.06.99)

(21) International Application Number: PCT/FI98/00967

(22) International Filing Date: 11 December 1998 (11.12.98)

(30) Priority Data:
974490 11 December 1997 (11.12.97) FI
981348 11 June 1998 (11.06.98) FI

(71) Applicant *(for all designated States except US)*: LK–PRODUCTS OY [FI/FI]; Takatie 6, FIN–90440 Kempele (FI).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: VISTBACKA, Tapani [FI/FI]; Heinäkuja 12, FIN–90440 Kempele (FI). NIIRANEN, Erkki [FI/FI]; Saukonkuja 1, FIN–91100 Ii (FI). ALA–KOJOLA, Jouni [FI/FI]; Liisankuja 1 as 1, FIN–90440 Kempele (FI).

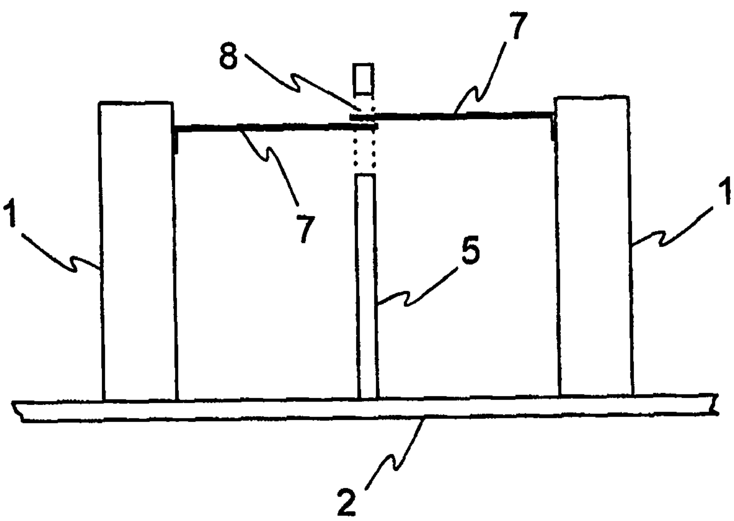
(74) Agent: BERGGREN OY AB; P.O. Box 16, FIN–00101 Helsinki (FI).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: RESONATOR STRUCTURE

(57) Abstract



The object of the invention is a coaxial resonator structure which enables the realisation of a high frequency filter, which has a small height and is realised with coaxial resonators. The frequency tuning means and the coupling tuning means of the resonator are realised with the aid of projections. The frequency tuning means adjusts the coupling of the resonator's open end to the outer wall or to the partition of the resonator structure, and the coupling tuning means adjusts the coupling of the resonator's open end to another resonator of the resonator structure or to the input or output of the resonator structure. The tuning means are preferably sheet–like projections. At the same time the tuning means act as capacitive loads, whereby it is possible to shorten the resonator's physical length compared to an unloaded resonator. Most preferably the frequency tuning means and the coupling tuning means are realised as projections of a single sheet–like component, whereby a resonator according to the invention is formed by two parts: a resonator and a capacitive loading part fastened to it, whereby the loading part at the same time acts as a frequency tuning means and a coupling tuning means. In a resonator structure of this type the tuning of the resonance frequency and the tuning of the coupling between the resonator circuits are combined by using a single mechanical part so that the tuning operations are mutually almost independent, both electrically and mechanically, whereby the tuning of the coupling and of the frequency substantially do not affect each other.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

Resonator structure

Object of the invention

The object of the invention is a resonator structure according to the preamble of claim 1. Most preferably the invention can be applied in resonator structures comprising coaxial resonators.

Technical background

In prior art coaxial high frequency filters the tuning of the resonators is typically realised by a screw adjustment, which requires a separate frequency adjustment screw and a nut to lock it. Particularly in covers with thin walls, particularly of aluminium, a screw requires also a separate fastener (threaded bushing). The patent US-5 023 579 presents the use of a screw for tuning the frequency of a resonator. A screw adjustment is also presented for instance in the patents US-4 224 587 and US-4 268 809. A screw adjustment has a disadvantage in that it increases the number of filter components and thus it increases the manufacturing costs and the price of the final product.

When high transmission power levels are used in coaxial filter structures with screw adjustment there is a further problem, namely the susceptibility to electric breakdown. When a screw adjustment is used the tip of the screw must often be located close to the open end of the resonator so that the screw can have a sufficient effect on the resonator and so that the frequency adjustment could operate. The close relation of the screw and resonator ends cause a risk of electric breakdown, because very high voltages may occur at the open end of the resonator when high powers are used.

In known filter structures the inductive or capacitive coupling between resonators is realised for instance by forming in the metal partition between the resonators a coupling opening, through which the required electromagnetic coupling can be realised. The coupling between the circuits through the opening can be adjusted for instance by a screw. Such a structure is presented for instance in the application publication WO-96/29754. Such a structure requires as components of the adjustment of the coupling a separate screw and a component required for locking the screw, which again increases the number of the required components. The patent US-4 216 448 presents the adjustment of the coupling between the resonators, which is realised by connecting to the top of the resonators round metal wires, with the aid of which the coupling between the resonators can be adjusted. The patent US-4 268 809 again presents a structure where the open end of a coaxial resonator receives a sheet of dielectric material, on which are connected metallic coupling tuning components, with which the amount of coupling can be tuned. Also this solution is complicated and expensive.

The patent US-4 292 610 shows how a resonator is shortened by capacitively loading the resonator at the open end. A solution of this kind can decrease the physical dimension of the resonator by several tens of percents without decreasing the quality factor too much. The patent US-4 224 587 presents an interdigital filter structure where the length of the resonator is decreased by a capacitive loading of the resonator. In the structure according to the invention the resonator is also shortened by loading the open end of the resonator, and to be more precise, by connecting a mechanical coupling means to the open end. Then the length of the straight section of the resonator could be shortened from about 70 mm to 23 mm, and at the same time the Q-value or the quality factor decreased only less than 30 % compared to a resonator of full length.

In series production the filters are typically tuned after the production. During production the filters are preset so that their characteristics are close to the desired value. For instance, an adjustment screw used for adjusting the frequency can be turned to a certain depth, where the resonance frequency of the filter is set close to the desired value. After the production each filter is typically fastened to a measuring equipment measuring the frequency response of the filter, and then the screw or other tuning means are adjusted so that the desired filter property obtains the desired value. With prior art filter structures this final tuning is cumbersome and time consuming.

Short description of the invention

An object of the invention is to realise a coaxial resonator structure having frequency tuning means with a construction which is as simple as possible. An object of the invention is also to realise a coaxial resonator structure where the means for tuning the coupling between the resonators have a structure which is as simple as possible. A further object of the invention is to realise a coaxial resonator structure where the number of components is as low as possible. A further object of the invention is to realise a low resonator structure according to the above mentioned objects.

These objects are attained by realising the frequency tuning means and the coupling tuning means as projections, whereby the frequency and the coupling can be tuned by bending the corresponding tuning means or projections. At the same time the projections act as capacitive loads, whereby the physical length of the resonator can be made shorter. Preferably the tuning means can be realised as projections of a single sheet-like component acting as a capacitive load, whereby only a single component must be fixed to the resonator.

The resonator structure according to the invention is characterised in what is presented in the characterising clause of the main claim. Other preferred embodiments of the invention are presented in the dependent claims.

The inventive structure allows the realizing of a coaxial resonator structure having a small height. The frequency tuning means and the coupling tuning means are realised with the aid of projections. The frequency tuning means controls the coupling of the resonator's open end to the outer wall or to the partition of the filter structure, and the coupling tuning means controls the coupling of the resonator's open end to the second resonator of the filter structure or to the filter structure's input or output. The tuning means are preferably sheet-like projections, and the coupling of the projections is controlled by bending their ends towards or away from the outer wall or the partition or the tuning means of the adjacent resonator. The area of the tuning means can be used to have an effect on the amount of the coupling. There can be one or more tuning means, whereby tuning means of different sizes can realise for instance a coarse tuning and a fine tuning of the frequency or of the coupling. The coupling of the tuning means can also be controlled for instance by changing the area of the tuning means. At the same time the tuning means act as capacitive loads, whereby the physical length of the resonator can be decreased compared to an unloaded resonator.

Most preferably the frequency tuning means and the coupling tuning means are realised as projections of a single sheet-like component, whereby the resonator according to the invention comprises two parts: a resonator and a capacitive loading component connected to the resonator, whereby the loading part at the same time acts as a frequency tuning means and a coupling tuning means. In a resonator structure of this kind the resonator's frequency tuning and the tuning of the coupling between the resonator circuits are combined by using a single mechanical component, so that the tuning actions are electrically and mechanically almost independent of each other, whereby the tuning action of the coupling and of the frequency do not have a substantial effect on each other.

Brief description of the figures

The invention is described in more detail below with reference to preferred embodiments presented as examples, and to the enclosed figures, in which:

Figure 1 shows the structure of a preferred embodiment of the invention;

Figure 2 shows the structure of another preferred embodiment of the invention;

Figure 3 shows the structure of figure 2 seen from another direction;

Figure 4 shows the structure of the coupling tuning means according to a preferred embodiment of the invention;

Figure 5 shows the structure of the coupling tuning means according to another embodiment of the invention;

Figure 6a shows the structure of the coupling tuning means according to a third embodiment of the invention;

Figure 6b shows the structure of the coupling tuning means according to a fourth embodiment of the invention;

Figure 7 shows the structure of a frequency tuning means according to a preferred embodiment of the invention; and

Figures 8A, 8B, 8C, and 8D illustrate resonator structures according to an advantageous embodiment of the invention, in which at least a part of the inner conductor and the ground plane 2 form a single continuous piece of material.

The same reference numerals and markings are used for corresponding parts in the figures.

Detailed description of preferred embodiments of the invention

Figure 1 shows in a perspective view a resonator structure according to a preferred embodiment of the invention. For the sake of clarity parts of the cover, such as the wall 5, are not shown in figure 1. The first end 1a of the resonator 1 is fixed with a galvanic joint to the bottom plate 2 of the structure, or to the ground plane 2 of the cover. A resonator upper part 3, which most preferably is made of a thin metal sheet, is fixed with a galvanic joint to the second end 1b of the coaxial resonator. At the same time the upper part 3 of the resonator acts as a capacitive loading means in order to shorten the physical length of the resonator 1. The frequency tuning means 4 are preferably bent towards the ground plane 2 in the manner shown in figure 1. The resonance frequency of the resonator can be tuned to a lower value by bending the frequency tuning means towards the metal wall 5 enclosing the resonator, whereby the wall most preferably is grounded. The frequency of the resonator can be tuned to a higher value by bending the frequency tuning means 4 towards the resonator 1. The frequency tuning means can have a areas of different sizes, whereby the effect of the frequency tuning differs when the positions of different tuning means 4 are changed. For instance in an embodiment like that of figure 1 having two frequency tuning means 4 the first tuning means can be used for a coarse frequency tuning, for instance on a frequency range of several tens of megahertz, and the second tuning means can be used for a fine frequency tuning on a frequency range of a few megahertz. According to the respective filter application there can also be more than two frequency tuning means, or for instance only a single one. One frequency tuning means may be sufficient in an embodiment where the structure according to the invention is used in a very narrow-band filter. Preferably the area of the one or more frequency tuning means 4 is dimensioned according to the desired tuning range.

Preferably the resonance frequency of the resonator can be tuned with the aid of the frequency tuning means 4 by bending the frequency tuning means with a special tuning key made of a dielectric material, whereby the tuning key has an almost negligible effect on the resonance frequency of the resonator. When the upper part of the resonator structure is selected as a sufficiently thick sheet and when the upper part 3 is fixed to the open end of the resonator structure in a sufficiently robust manner, this provides a mechanically robust structure, whereby for instance mechanical vibrations and mechanical shocks will not affect the resonance frequency nor any other characteristics of the resonator. Then also the tuning of the resonator is simple, because the torsion caused by the bending will not bend the whole resonator structure.

During the production stage of the resonator the resonance frequency of the resonator can be preset close to the desired value, and after the production it can be tuned to the desired value with the aid of the frequency tuning means 4. The presetting can be realised for instance by a suitable design of the upper part 3 of the resonator.

Further figure 1 shows the coupling tuning means 7, with which the coupling between two resonators of the resonator structure can be adjusted. The coupling between the resonators is thus mainly determined by the dimensions and the location of the opening 8, and by the size of the coupling tuning means 7 and by their mutual distance.

Thus a part of the coupling between the resonance circuits of the resonator structure can be realised by suitable dimensioning of the coupling opening 8. In a preferred embodiment of the invention the main part of the coupling between the resonators is formed through the opening 8, and the fine tuning with the coupling tuning means 7. This provides an insensitive resonator structure which is easy to tune. For instance, a coupling of 20 MHz between the circuits can be realised so that the opening creates a coupling of 15 MHz and the rest of 5 MHz is created by the tuning means. A larger opening can realise a larger inductive coupling, and with a smaller opening the case is the opposite.

In such cases where the basic coupling between the resonance circuits, through the coupling opening is too strong, it is possible to make close to the grounded end 1a of the resonator a second coupling opening in the partition 5, which separates the resonance circuits. The effect of a second opening of this type is the opposite compared to a coupling which is created through a coupling opening adjacent to the open end of the resonator. Then the coupling can be tuned to an approximately suitable level with aid of the coupling opening formed close to the grounded end of the resonator, whereby the fine tuning of the coupling can be realised by adjusting the position of the coupling tuning means 7.

The coupling openings 8 can be formed in the partitions, for instance by punching or in any other way according to prior art. With the aid of the structure according to the invention all coupling openings can be made equally large, so that in series production they can be made with a single tool, which reduces the manufacturing costs. In such an embodiment any required coupling strength differences between the resonators can be realised with the aid of the coupling tuning means 7.

Figure 2 shows a structure according to another preferred embodiment of the invention. Figure 3 illustrates the structure of figure 2 seen from a different direction. In this embodiment there is no separate upper part 3 of the resonator, but the frequency tuning means 4 and the coupling tuning means 7 are separate parts, which are galvanically fixed to the resonator 1. In figures 2 and 3 the frequency tuning means 4 and the coupling tuning means 7, more particularly their shafts 4', 7', act further as means which capacitively load the resonator in order to shorten the physical length of the resonator. For the sake of clarity the shafts 4', 7' are marked in figures 2 and 3 only at the location of one resonator.

The coupling tuning means 7 and the frequency tuning means 4 illustrated by the exemplary embodiment in figures 2 and 3 could naturally for each resonator also be realised as correspondingly shaped projections of a single integral body, whereby the projections in a fully corresponding manner would enable the realisation of the alternative structures and embodiments described with the aid of figures 2 and 3.

The figures 2 and 3 also illustrate a structure according to the invention where the same projection is used as two coupling tuning means 7. In figures 2 and 3 one projection creates a coupling to two other resonators.

In the embodiment of the figures 2 and 3 the open ends of the coupling tuning means 7 are realised differently from the embodiment of figure 1. In the embodiment of the figures 2 and 3 the ends of the coupling tuning means 7 are bent so that the bent ends of the coupling tuning means of two adjacent resonators are substantially parallel, at least along a certain part. By bending the ends of the coupling tuning means closer to each other it is possible to amplify the coupling between the resonators, and by bending the ends of the coupling tuning means 7 farther from each other it is possible to weaken the coupling between the resonators. With the solution for the coupling tuning means according to the embodiment of figures 2 and 3 it is possible to realise a very strong coupling between the resonators, or a so called over-coupling, if it is desired to form a strong zero in the frequency response of the resonator structure, whereby the attenuation of the resonator structure is very high at a frequency corresponding to the zero. The figures 2 and 3 further illustrate the fact that more than only one coupling tuning means 7 can be fixed to the same resonator, for instance in order to couple to the resonators the input and output signals of the total resonator.

In a resonator structure structure according to the invention it is possible to add a separate capacitive loading means to the embodiment presented in the figures 2 and 3, preferably for instance a sheet-like body in order to create a capacitive load and to shorten the physical length of the resonator.

Figure 2 illustrates in an example also a preferred embodiment of the invention where the tuning means are fastened at another location of the resonator, different from the open end of the resonator. In the exemplary embodiment of figure 2 the tuning means are fastened closer to the resonator's open end than to its grounded end, but not directly to the open end as in the embodiment of figure 1. In a structure like this the tuning means are not fastened to the resonator at a point where the occurring voltages reach a maximum, i.e. at the open end, but in a place where the voltages are lower. This contributes to increasing the air gap between the open end and the grounded parts, whereby the risk of an electrical breakdown is lower than in prior art solutions. Also in such preferred embodiments of the invention where the tuning means 4, 7 are realised as projections of a single body, as for instance in figure 1, this single body can be fastened at the desired location on the coaxial resonator between the open and the grounded ends of the coaxial resonator. Further it is possible to increase the distance from the open end to said grounded parts, such as the cover structure, by shortening the resonator with the aid of a capacitive load in any of the ways described in this application, for instance with the aid of the capacitive load created by the separate upper part 3, or with the aid of the capacitive load created by the shafts of the tuning means. For instance with the aid of the area of the loading means or the selection of the fixing point of the loading means it is possible to control the magnitude of the capacitive load. If the frequency tuning means and the coupling tuning means are separate components, then in the different embodiments of the invention they can be fixed independently of each other also at different distances from the open end of the resonator. Of course they can also be fixed at a substantially identical distance from the open end, as is shown in figure 2.

The fixing point of the tuning means can further have an effect on the resonance frequencies of the resonator structure. This is particularly advantageous in series production of the resonator structures, because then it is possible to manufacture identical resonators and resonator structure covers for many different resonator structure applications, and the resonance frequencies can then be determined at least partly with the fixing points of the tuning means. In some prototype structures it was possible to shift the resonance frequency up to 300 MHz with the aid of the fixing point of the tuning means, when the basic frequency was about 1800 MHz. Such tunability makes it possible to use the resonator structures based on the identical resonators and covers in devices of many different mobile communication systems.

The dimensions of the tuning means can be selected according to the requirements of the respective application. If a strong coupling between the circuits is required, then the coupling tuning means can be wide in that part where their open ends are close to each other. If a strong coupling between the circuits is not required, then the open ends of the coupling tuning means can be located far from each other, or they can have a small area.

The tuning of the coupling tuning means can be made in a manner similar to the tuning of the frequency tuning means, for instance with a tool made of a dielectric material. In order to provide the desired couplings the coupling tuning means can also be preset during the assembly or the manufacturing stages, depending on the respective requirements.

The shape, the size and the number of the one or more coupling tuning means and the one or more frequency tuning means can be selected according to the requirements of the respective application, and the invention is not limited to the examples presented in this application.

Figure 4 shows a preferred embodiment of the invention where the coupling tuning means 7 extend partly through the opening 8 in the partition 5, so that the coupling tuning means 7 of adjacent resonators are partly overlapping. In an embodiment of this kind the strength of the coupling can be increased by bending the members 7 towards each other, and decreased by bending the members 7 away from each other.

Figure 5 illustrates a preferred embodiment of the invention where the coupling tuning means 7 has two branches 7a, 7b. With the aid of two differently sized branches it is possible to realise the coarse tuning and the fine tuning of the coupling.

The figures 6a and 6b illustrate a preferred embodiment of the invention where there is also other matter than air as the dielectric between the open ends of the coupling tuning means 7. In figure 6a the partly overlapping ends of the coupling tuning means 7 are fixed to a dielectric body 21, which again advantageously can be fixed to the partition 5. A solution of this kind is mechanically more robust than an air insulated solution, so that the resonator structure can better withstand vibration and shocks. Figure 6b illustrates an embodiment where the ends of the coupling tuning means 7 are side by side and fixed to a dielectric body 21, which also in this embodiment can be advantageously fixed to the partition 5. In the embodiments shown in the figures 6a and 6b the dielectric body is not exactly at the ends of the coupling tuning means 7, whereby the strength of the coupling can be adjusted in the above described manner by bending the ends of the coupling tuning means 7.

However, the invention is not limited to the tuning of the strength of the coupling and to the tuning of the frequency by bending the corresponding means 4, 7, but the tuning can also be performed by shaping the corresponding means 4, 7 in other ways, for instance by cutting the means 4, 7 or by adjusting their area in some other manner.

Figure 7 illustrates an embodiment where the frequency tuning means 4 is fixed via the dielectric body 21 to the partition 5 in order to provide a mechanical stability. Also in this embodiment the frequency can be tuned by bending the end of the frequency tuning means 4 in the manner described above, or for instance by reducing the area of the end of the frequency tuning means 4, for instance by cutting.

The figures 6a, 6b and 7 show only some examples of the use of a dielectric material between different members. However, the invention is not limited to the use of a certain dielectric body 21, but the frequency tuning means 4 and the coupling tuning means 7 could for instance be coated by plastic or other isolating material, whereby for instance the coupling tuning means of resonators standing side by side can be fixedly glued to each other at one or more points, or for instance the frequency tuning means 4 can be fixedly glued to the partition at one or more points.

The solution according to the figures 4, 5, 6 and 7 can be used in all preferred embodiments described in this application, as in such embodiments where the frequency tuning means 4 and the coupling tuning means 7 are projections of an integral component, and in such embodiments where the frequency tuning means and the coupling tuning means are components separately fixed to the resonator.

In the previous examples of various embodiments of the invention, the resonator i.e. the inner conductor 1 was specified as being in galvanic contact with the ground plane 2. Figures 8A, 8B, 8C, and 8D illustrate resonator structures according to an advantageous embodiment of the invention, in which at least a part of the inner conductor and the ground plane 2 form a single continuous piece of material. Further, the walls 5 of the structure can also be a part of the same continuous piece of material as the ground plane 2 and the inner conductor 1. Such a combined structure is simple to manufacture, since the step of fixing the inner conductor to the ground plane 2 is not required in such an embodiment. This advantage is especially important in cases, where a resonator structure comprises a large number of resonators. The structure can be manufactured for example using extrusion, casting or milling. The combined structure can be manufactured very accurately to desired dimensions, especially when using extrusion to form the structure. The combined structure produces also less intermodulation artefacts to the signals processed by the structure.

Figure 8A shows a cross section of a structure according to an embodiment of the invention, in which at least a part of the inner conductor and the ground plane 2 form a single continuous piece of material. In the example of figure 8A, the walls 5 of the structure are also a part of the same continuous piece of material as the inner conductor i.e. resonator 1 and the ground plane 2.

For clarity, coupling tuning means 7 and frequency tuning means 4 are not illustrated in figures 8A, 8B, and 8C.

Figure 8B illustrates a cross section of an advantageous embodiment of the invention, in which the corner 24 between the inner conductor 1 with the ground plane 2 is rounded. The rounding of the corner 24 is advantageous, since it has the effect of further decreasing the amount of intermodulation artefacts created into the signals processed by the structure. In the example of figure 8B, the walls 5 of the structure are also a part of the same continuous piece of material as the inner conductor i.e. resonator 1 and the ground plane 2.

The continuous structure such as illustrated in figures 8A and 8B is advantageous, since there is no junction between the inner conductor 1 and the ground plane 2. The electrical coupling over a junction may be imperfect for several reasons, for example due to inaccurate machining of the junction surfaces, insufficient force used to create the junction, oxidising of the junction surfaces and contamination of the junction surfaces. Such imperfections may cause the electrical contact between the inner conductor and the ground plane to be less than perfect, for example to have a non-linear voltage to current relation. Such imperfections can create intermodulation artefacts to the signals processed by the structure. The base of the inner conductor is especially critical in this respect, since a current maximum exists at the base of the inner conductor, when the structure operates at a resonating frequency. A high current increases the effect of any eventual imperfections of the junction. A continuous structure therefore eliminates a junction, which is a main source of intermodulation artefacts.

In an advantageous embodiment of the invention, the inner conductor 1 comprises more than one parts, one of which is a part of the same continuous piece of material as the ground plane 2. Figure 8C illustrates the cross section of an example of such an embodiment. The inner conductor comprises two parts 1A,1B which are electrically connected to each other. Part 1B is a part of the same continuous piece of material as the ground plane 2 and walls 5. In this embodiment, any coupling or frequency tuning means can be fixed to the part 1A either before or after the fixing of part 1A to part 1B. Any coupling or frequency tuning means can also be fixed to the part 1B. The inner conductor 1 can also comprise more than two parts 1A, 1B.

One example of advantages of an embodiment of the invention, in which the inner conductor comprises more than one parts, is that while the creation of a junction at the base of the inner conductor can be avoided with such a structure, parts of the inner conductor can for example be manufactured from different material than some other parts in order to create a temperature compensated structure. By careful selection of materials on one hand for the element comprising base 1B of the inner conductor, ground plane 2 and the walls 5 and on the other hand for a second part 1A of the inner conductor, the effect of the changing of dimensions of said element on the resonance frequency of the structure can be compensated by the change of dimensions of the second part 1A.

Another example of advantages of an embodiment of the invention, in which the inner conductor comprises more than one parts, is that one base structure can be used in different resonator structures with differing properties by tailoring the second part 1A and/or further parts of the inner conductor according to the desired properties of the resonator structure. For example, any coupling or frequency tuning means may be manufactured as integral extensions of the second part 1A, whereby the tuning means do not need to be separately fixed to an inner conductor.

Although a structure in which the inner conductor comprises more than one parts has at least one junction within the inner conductor, it is not as large a disadvantage regarding intermodulation artefacts as a junction at the base of the inner conductor, since a junction between the ends of the inner conductor are generally not located at a current maximum.

The parts 1A,1B of the inner conductor can be fixed to each other using any known fixing method creating also an electrical contact between the parts, and the invention is not limited to any specific method of fixing the parts to each other.

Figure 8D illustrates a further example of a structure according to an embodiment of the invention, in which at least a part of the inner conductor 1 and the ground plane 2 form a single continuous piece of material. As figure 8D shows, an inventive resonator structure may comprise more than one resonators. Figure 8D illustrates further, that a resonator structure according to the invention may comprise resonators having a single part 1 and resonators comprising more than one parts 1A,1B.

Further, figure 8D illustrates such an embodiment of the invention, in which a coupling tuning means 7 is an integral extension to a part 1A of an inner conductor 1, i.e. part of the same continuous piece of material. Figure 8D also shows walls 5.

The assembly of a resonator structure according to the invention is simpler than the assembly of prior art solutions, because the number of required components is lower. Further the electrical performance of the solution according to the invention is better than the prior solution with a screw adjustment. Thus a resonator structure according to the invention is more economical, easier and faster to manufacture in series production than the prior art solutions. A further advantage provided by the easy and wide tunability of the solution according to the invention is that the product development of different resonator structure versions having different frequencies and bandwidths is easier, and the time required by the design is reduced, which saves costs in the product development and in the production. When the number of required components is reduced the management of the product ranges will be improved.

The upper part 3 of the resonator, the frequency tuning means 4 and the coupling tuning means 7 can be formed for instance of a thin copper sheet or of another suitable sheet material, such as for instance of a sheet manufactured from another metal, or of a metal coated dielectric sheet, or of a dielectric sheet, which is metallised after coarse shaping. Advantageously also the upper part 3 of the resonator, the frequency tuning means 4, and the coupling tuning means 7, can be coated with silver, gold, or with another material with a very good electric conductivity.

The above described galvanic joints can be made for instance by soldering, but also by other known means, such as spot welding or by gluing with an electrically conductive adhesive.

Above we described such examples where the frequency tuning means 4 and the coupling tuning means 7 are substantially separate components, which both also act as capacitive loads. However, this does not limit the invention, but in a solution according to the invention it is sufficient that at least one of them, or that component to which the means are fastened or which forms the projections, acts as the capacitive load.

Although the solution according to the invention is particularly well adapted to be used in such resonator structures where there are more than one coaxial resonator, the solution according to the invention can also be used in such resonator structures, which have only one coaxial resonator. Then with the aid of the coupling tuning means 7 it is possible to adjust the strength of the coupling to the input and output of the resonator structure, or simultaneously to further resonator structure stages realised by other techniques.

The inventive resonator structures can be advantageously used in filter structures. The resonator structure according to the invention can be particularly advantageously used in mobile stations and in different devices of cellular network systems, such as in base station filters for the 900 MHz GSM and in base station filters for the 1800 MHz DCS and the 1900 MHz PCS. However, the invention is not limited to these examples, but the filter solution according to the invention can be used in any other applications.

Above the invention was described with reference to some of its preferred embodiments, but it is obvious that the invention can be modified in many different ways within the inventive idea defined by the enclosed claims.

Claims

1. A resonator structure having at least one coaxial resonator (1), **characterised** in that the resonator structure comprises:
- at least one frequency tuning means (4) for tuning the resonance frequency of the coaxial resonator,
- at least one coupling tuning means (7) for adjusting the strength of the coupling between the coaxial resonator and other members of the resonator structure, and
- at least one capacitive loading means (3, 4', 7') of the coaxial resonator,
whereby at least one of said tuning means (4, 7) forms an integral body with at least one of said capacitive loading means (3, 4', 7').

2. A resonator structure according to claim 1, **characterised** in that said tuning means (4, 7) are realised as projections of a single integral component (3), which is the capacitive loading means of the coaxial resonator.

3. A resonator structure according to claim 1, **characterised** in that said tuning means (4, 7) are manufactured of a sheet-like material.

4. A resonator structure according to claim 3, **characterised** in that the sheet material used for the manufacturing of said tuning means (4, 7) is copper sheet coated with a silver layer.

5. A resonator structure according to claim 1, **characterised** in that said tuning means (4, 7) are realised as separate bodies fastened to said at least one coaxial resonator.

6. A resonator structure according to claim 1, **characterised** in that at least one of said tuning means (4, 7) is fastened to said at least one coaxial resonator between its open and grounded ends.

7. A resonator structure according to claim 1, **characterised** in that said tuning means (4, 7) are fastened at the open end of said at least one coaxial resonator.

8. A resonator structure according to claim 1, **characterised** in that said resonator (1) is a part of the same continuous piece of material as the ground plane (2) of the resonator structure.

9. A resonator structure according to claim 1, **characterised** in that a part (1B) of said resonator (1) is a part of the same continuous piece of material as the ground

plane (2) of the resonator structure.

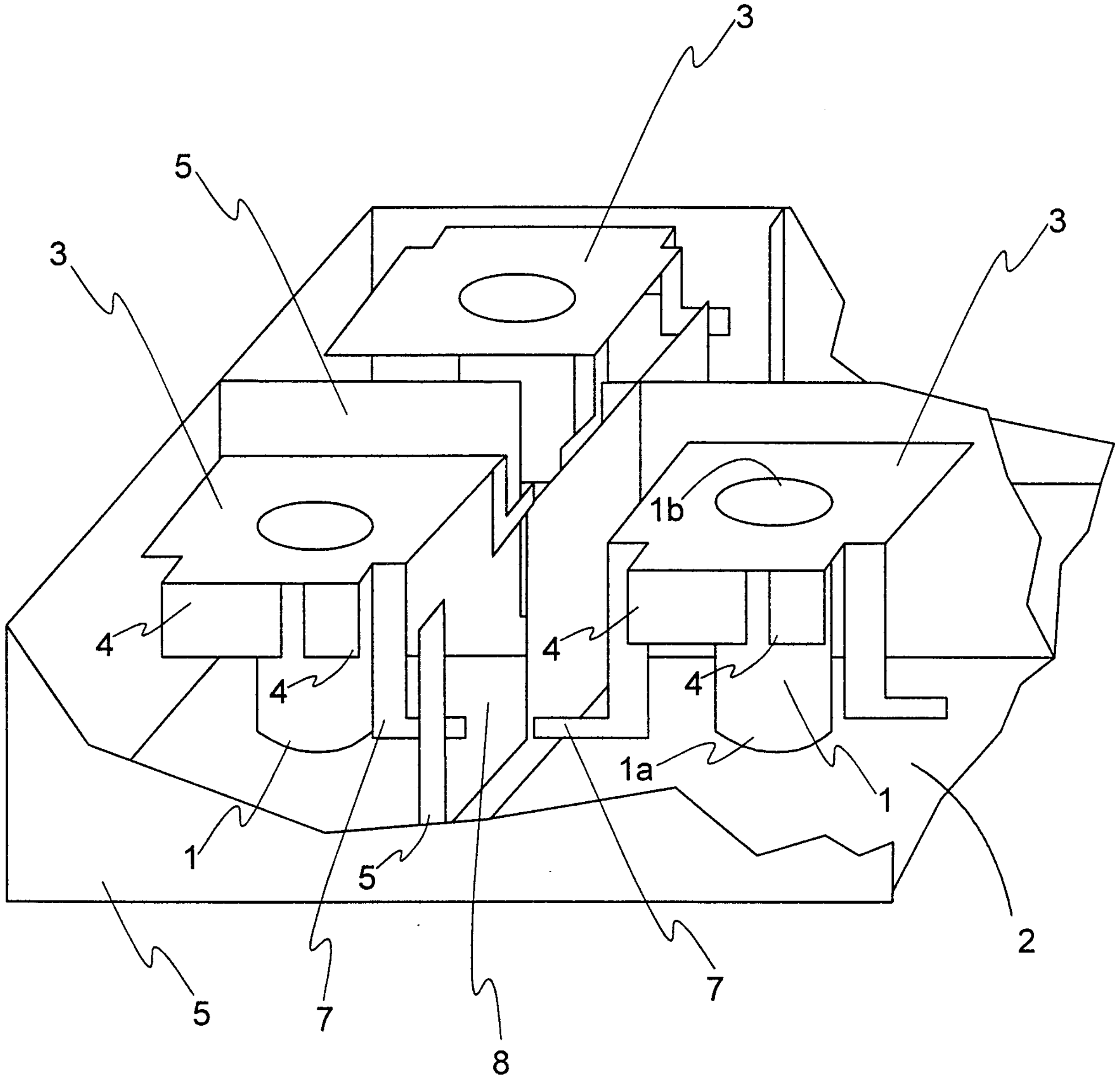


Fig. 1

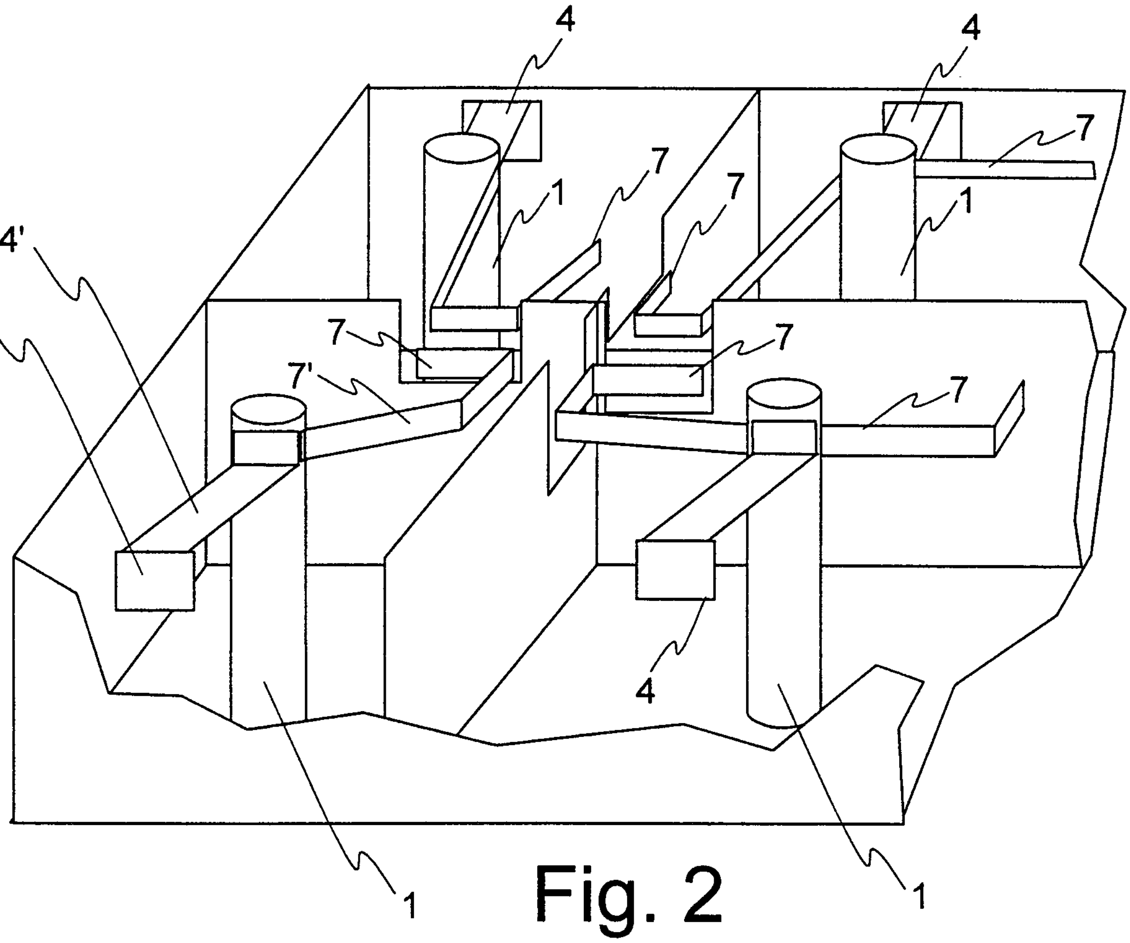


Fig. 2

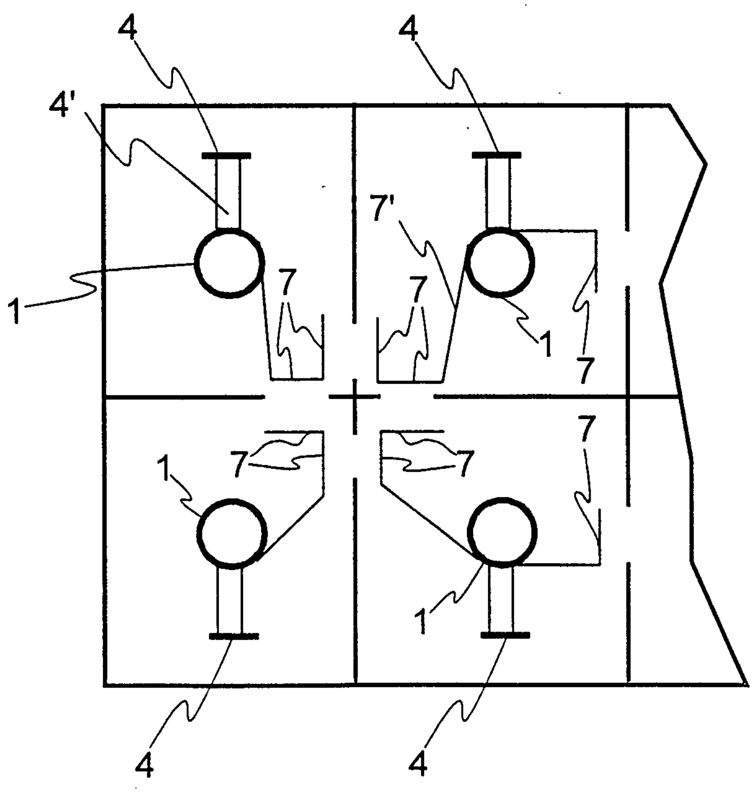


Fig. 3

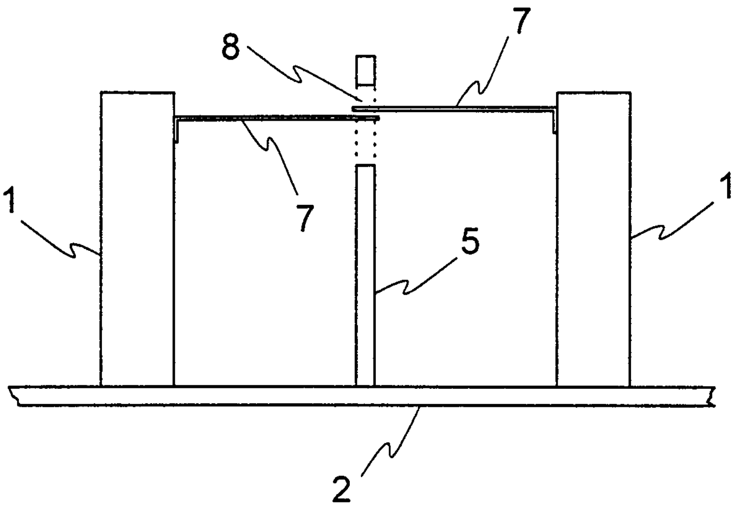


Fig. 4

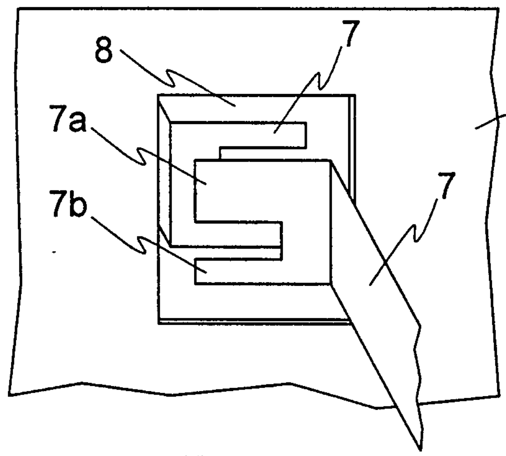


Fig. 5

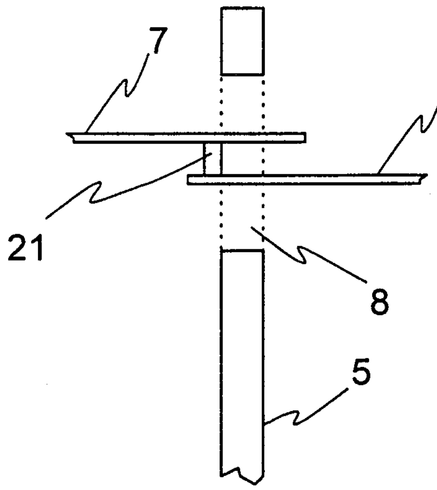


Fig. 6a

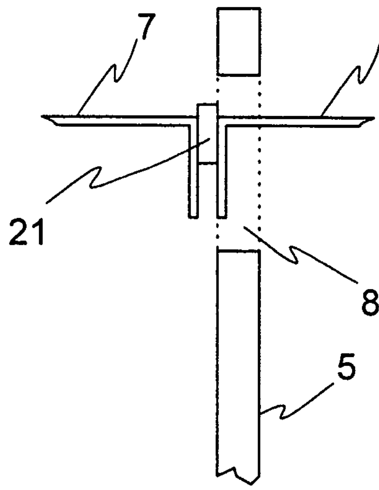


Fig. 6b

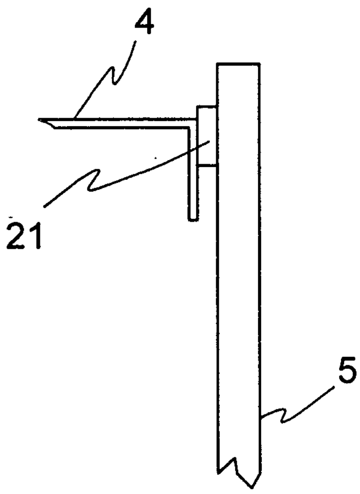


Fig. 7

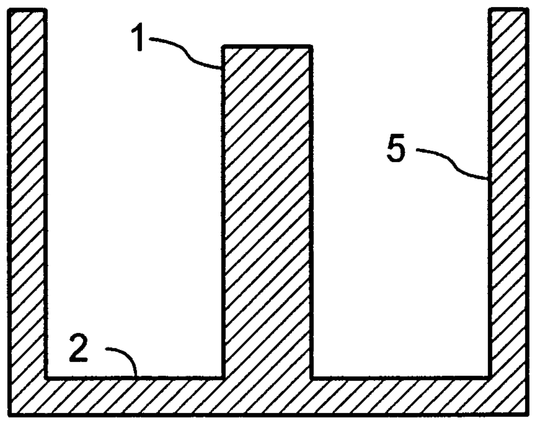


Fig. 8A

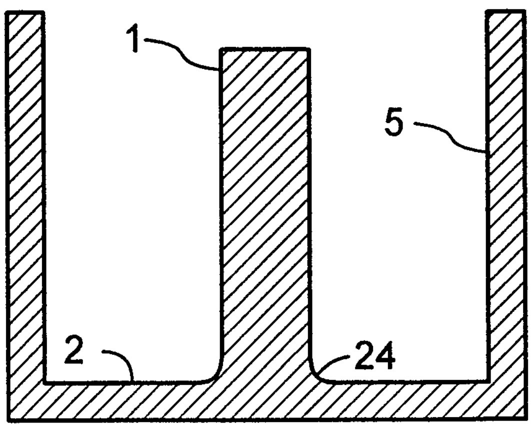


Fig. 8B

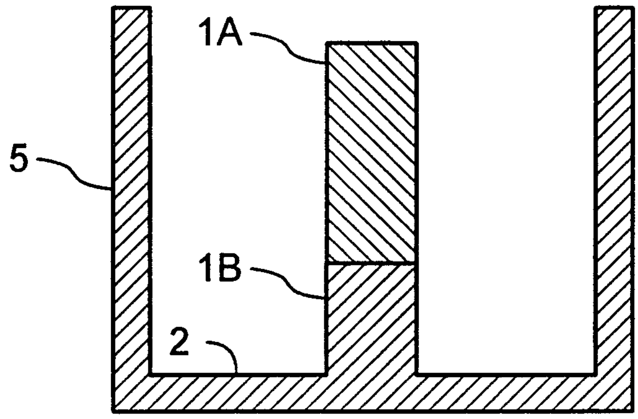


Fig. 8C

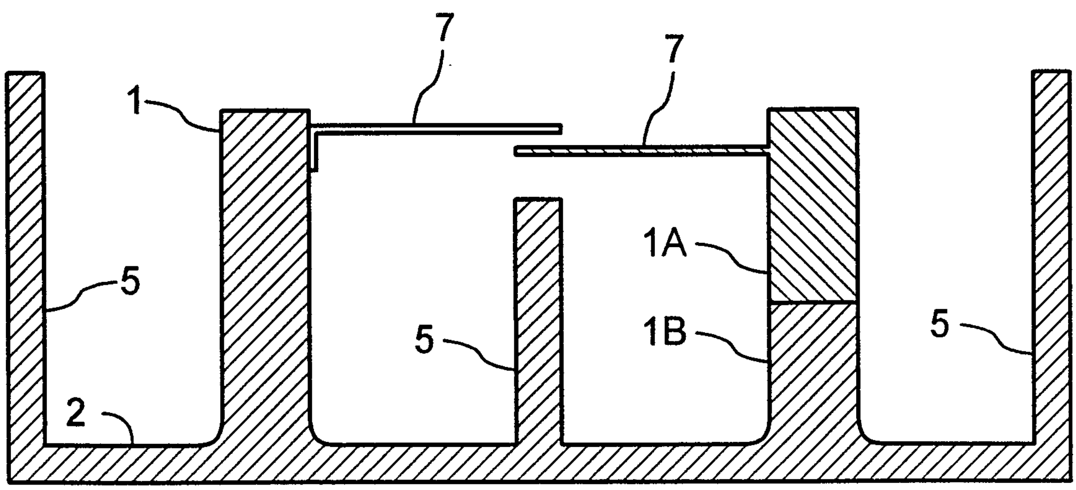


Fig. 8D