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(54) **Adjustable ceramic filter.**

(57) A filter comprises several resonators in a dielectric block (1). An electrically conductive cover (10) is provided adjacent the top surface (3) of the dielectric block. The cover has a respective cut-out tab portion (7_1-7_7) located over each of the resonator holes (6_1-6_7) whereby the individual tabs may be bent to adjust the resonant frequency of the associated resonator. Alternatively, the coupling between resonators may be adjusted if the bendable tabs (11_1-11_7) are located between adjacent resonators. A cover (9) with bendable tabs, may also be disposed adjacent a side face (5) of the dielectric block, the tabs (12_1-12_7) being provided between resonators whereby the inter-resonant coupling may be adjusted.

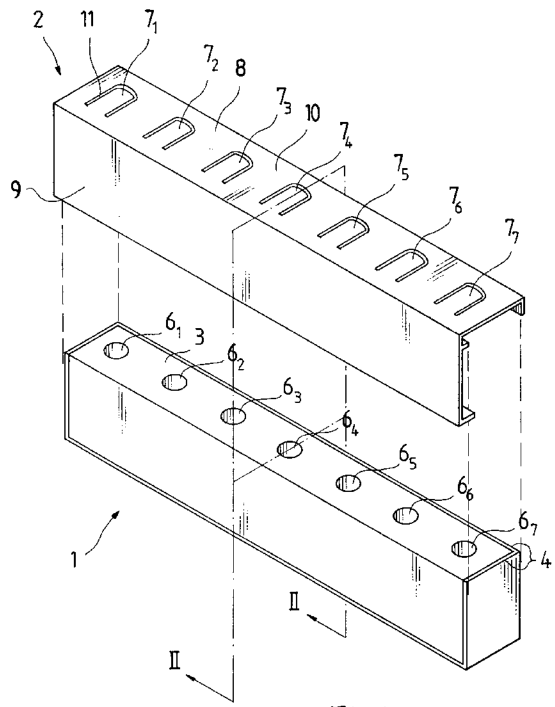

Fig.1

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This invention generally relates to an adjustable dielectric filter, particularly a ceramic radio frequency filter.

Ceramic filters comprising several resonators are formed by quarter-wave transmission lines located in a row, as is well known. The basic design of the filter corresponds to an air insulated comb filter. The filter comprises a block of dielectric material with one or more holes arranged in a row, the holes extending through the block from its top surface to the bottom surface. Further it has electrodes for the input and output signals at a certain distance from the respective hole. The block is entirely coated by a conductive coating, usually of silver, copper, or their compound. The coating also covers the surfaces in the holes, but leaves uncoated the upper block surface or at least a part of the upper block surface around the holes. Thus parallel resonance circuits are formed corresponding to coaxial resonators where the inner conductor is the coating in the hole and the outer conductor the coating covering the outer surfaces of the block, whereby the field energy exists in the dielectric material. Each resonator thus comprises a shorted transmission line, because the coating at the bottom of each hole directly joins the coating of the outer surface of the block. At the top of the transmission line there is a load capacitance consisting of the capacitance between the top of the hole and the coating on the outer surface of the block. The resonators in the row are like the teeth in a comb, joined by the continuous coating on the bottom surface of the block, hence the term comb filter. If the shorted ends of adjacent resonators alternate with a capacitively loaded high impedance end, the result will be a so called interdigital design. The length of the hole or of the transmission line is selected so that it matches the quarter-wave length of the resonance frequency. The advantage compared to an air insulated resonator is that by using a dielectric material the length of the resonator can be reduced by the factor $\sqrt{\varepsilon_r}$, where ε_r is the dielectric constant of the material, because the length of a wave propagating in the dielectric material is reduced by this factor. This renders possible a small sized filter, particularly suited for the use in portable radio equipment. The coupling between adjacent resonators is effected through the dielectric material. The block can be made of any suitable material with low loss, and a high dielectric constant with a negligible temperature dependence. Suitable materials are e.g. compounds based on titanate.

The dimensions and the dielectric constant of the ceramic material in the resonator structure will thus determine the characteristic impedance and the resonance frequency of the structure. It might be said that the resonance frequency desired for each resonator and the coupling to the adjacent resonator is calculated when the filter is designed. Tolerances of the dielectric material and changes in the block dimensions after sintering will usually cause a need to tune the obtained filter. The tuning of the filter includes both adjusting the coupling between the resonators, which will have an effect on the width of the filter's pass band, and tuning the resonance frequency, which will have an effect on the center frequency. As the coupling between the resonators is affected through the dielectric material, it can be adjusted by changing the effective width of the dielectric material and the distance between adjacent resonators. The effective width can be adjusted in numerous known ways, e.g. by making grooves in the dielectric material between the resonators, either in the surface where the high impedance (capacitively loaded) ends open, or by changing the pattern formed by the conductive surface on the surface where the high impedance ends open. Examples of this are presented in the US patent 4,716,391. The application DE 3 732 850 describes a way to affect the coupling, by making a slot in the uncoated surface of the ceramic body at a point of a standing wave voltage maximum at the resonance frequency. During tuning this slot is enlarged with a laser or by cutting. It is also possible to drill holes between the resonators and to construct tuning screws moving in said holes, having an effect on the coupling between the resonators, as described in the patent US 4,450,421. These known methods are inconvenient in practice, because due to the hardness of the material it is difficult to remove ceramic material between the resonators, and the use of a tuning screw adds to the mechanical parts without always providing the required tuning stability.

The resonance frequency of a single resonator could also be changed by several known methods. It is possible to use an earthed tuning screw pushed into the resonator through the high impedance end. Turning the screw will affect the capacitive load of the resonator. Screw arrangements of this kind are cumbersome, they contain several parts, and they are mechanically unreliable. Another known method is to remove conductive material in order to reduce the load capacitance and thus to increase the resonance frequency. Because the tuning is made in only one direction, the resonator initially has to be designed for a lower frequency than the final frequency. The publication Electronics, July 14, 1983, Tomoki Uwano: 'Ceramic-filled resonator cuts costs of radiotelephone filter', presents an adjusting method where a tuning shaft to be rotated from its end extends through a resonator hole and rotates a trimmer capacitance at its upper end. The design is rather complicated to be realized in practice. US patent 4,157,517 describes a method where conductive material is removed from or added to the high impedance end. It is also known to remove conductive material from the inner conductor of the resonator at the lower end area where it joins the coating on the outer surface of the body, whereby the equivalent inductance of the short circuit is increased, reducing the resonance frequency. The resonator can also be made so that conductive material, e.g. a conductive paint, is added or removed at said location, whereby an addition increases and a removal decreases the resonance frequency. Such a method is described in PCT application WO 89/01245. A disadvantage of these material removing methods is that they require the use of sand blasting, laser machining or diamond drilling, resulting in an additional work phase in the production. Usually it is not possible to perform measurements and adjustments at the same time. Further the material removing or adding methods are not very sensitive, in other words it is difficult to obtain very small frequency changes. US patent 4,965,537 presents a method enabling the frequency to be changed in steps, when the target frequency is e.g. 836.5 MHz. It utilizes 7 different ready made masks of conductive material patterns to be transferred onto the upper surface of the body. In the first phase the filter's center frequency is measured without any mask, and thereafter a mask pattern is chosen that changes the center frequency by the desired amount when it is transferred onto the upper surface. Using one transferable mask it is possible to adjust the center frequency between 1.020 GHz and 836.5 MHz. Transmission losses and attenuation required of the filter are better achieved using this method than by e.g. sand blasting techniques, but the method is not well suited when it is desired to change the characteristics of a finished filter, placed in a metal housing.

According to the present invention there is provided a filter comprising a dielectric block with top, bottom and side surfaces, and having at least one hole extending from the top surface to the bottom surface, the interior surface of said hole(s) and the surfaces of the block being substantially covered, with the exception of at least a part of the top surface and/or one side surface, with conductive material in order to provide a transmission line resonator at each hole, electrode means being present on the upper surface and/or on said one side surface for providing electrical signal coupling to the resonators, characterised in that an electrically conductive member is disposed adjacent the top surface and/or said one side surface of the block, said electrically conductive member having at least one cut-out portion which can be bent towards and away from the block to adjust the tuning of at least one of the resonators.

A filter in accordance with the invention permits adjustment of the frequency of the resonators and the coupling between them, which is fast and easy to realize and without the above mentioned disadvantages. The adjustment works in both directions and may be performed at the same time as measurements.

In one embodiment a ceramic resonator block of a known type is enclosed at least on the sides and at the top by a metallic or metallized housing acting both as a protective cover and as an earthed mounting case on a printed board. At the capacitive ends of the resonators the housing is provided, by using a suitable punching tool, with cut-out portions forming adjustment parts, i.e. a tongue which can be bent towards the ceramic block or away from it. This has an influence on the load capacitance of individual resonators and thus on the resonance frequency, because the housing is earthed. In a further embodiment tongues may be cut into the housing in an area between the capacitive ends of the resonators. This will have an effect on the capacitive stray field between the resonators and thus also on the coupling between them. The tongues can also be cut in the sides of the housing, the sides being parallel with the axes of the holes, whereby the tongues are cut so that they are located in the area between the holes. By this it is also possible to affect the capacitive stray field. In this case the side wall of the ceramic block corresponding to this side is not covered with a conductive coating.

The invention is now described, by way of example, in more detail with the aid of the enclosed figures, in which:

Figure 1 shows an exploded view of a filter, in accordance with the invention,

Figure 2 shows a section of the resonator hole along line II - II of Figure 1, when the filter is assembled,

Figure 3 shows a different filter in accordance with the invention, and

Figure 4 shows a section of the filter along line IV - IV of Figure 3.

With reference to Figure 1 and 2 a typical ceramic filter comprises a block of dielectric material, rectangular in section and with holes 6_1 - 6_7 extending from the top surface 3 to the opposite bottom surface. The number of resonator holes is not an essential feature of the invention. The ceramic block can be entirely coated, except for the top surface 3, with conductive coating 4, e.g. with a silver-copper-compound. The inner walls of the holes 6_1-6_7 are also coated in the same process. The top surface 3 is usually provided with a circuit pattern, a mask, with spots for input and output signal conductors, and possibly with short transmission lines, capacitor plates etc. These details not shown are well-known to a person skilled in the art, and so will not be described further. The mask, the components and the connectors (not shown) can also be located on the side surface 5 of the dielectric block, the side surface then being uncoated like the top surface. Figure 1 shows just this case, although the invention is not limited to this embodiment. To the dielectric block 1 is fastened a cover 2 of conductive material covering the sides 3 and 4 of the ceramic block 1, so that the surface 9 of the cover is not quite abutting the surface 5 and so that the surface 10 is not quite abutting the surface 3. The cover is most easily fastened by soldering it at the edges to the coating 4 on the ceramic block 1. At each resonator hole 6_1 - 6_7 U-shaped areas 11 are cut away from the surface 10 of the cover 2 so that there are formed tongues 7_1 - 7_7 which can be bent away from the surface 10. The tongues are bent slightly downwards before the cover is fastened. When the cover 2 is fastened the filter is ready to be tuned. In the present embodiment the filter includes seven resonators, each having above the resonator hole a tongue made in the surface 10 of the cover 2, i.e. the tongue 7_1 is above the hole 6_1, and so on. The cables of the measuring equipment are connected to the filter connectors (not shown) and the filter's characteristic curves may be examined on the measuring equipment screen. If it is now found that e.g. the passband curve does not have quite the right form, this form and its center frequency can be affected by acting upon the resonance frequency of individual resonators. A tongue above an individual resonator hole is bent towards the hole or away from it, depending on the required decrease or increase of the resonance frequency. When required this adjustment is made for each resonator tongue 7_1-7_7. The effect of bending a tongue can simultaneously be seen on the measuring equipment screen, enabling a rapid adjustment.

Figure 2 shows in section how the tongue is used to adjust the resonance frequency. The dielectric material (shown cross-hatched) is partly covered by a conductive coating 4. The hole 6_4 of the resonator is also coated, and at the bottom end the coating joins the outside coating. On the side 5 there is, as already was mentioned, a conductor mask (not shown). The cover 2 is soldered at its edges to the coating 4 of the dielectric block, and as is shown in the Figure, the walls 9 and 10 of the cover 2 are spaced apart from the block walls 5 and 3. The side wall 9 of the cover 2 is also supported by a ridge or pin-like projections in the form of spacing members 13 against the side wall 5 of the block 1, the pins stiffening the cover 9 and locating it in parallel with side 5. As the walls 5 and 3 are not coated, there is a capacitive field between these walls and the walls of the cover. In a known way the capacitive load of the resonator high impedance end is formed mainly by the capacitor formed by the upper edge of the hole 6_4 and the surface 10 of the earthed cover. When the tongue 7_4 is bent towards the hole 6_4, this means that the capacitance is increased, increasing the capacitance of the parallel resonance circuit of the resonator and thus decreasing the resonance frequency. Bending the tongue 7_4 away from the hole accordingly increases the resonance frequency. By adjusting the position of the tongue at each resonator hole in this way it is possible to adjust the frequencies of the resonators so that the desired center frequency and the characteristic curve of the filter is obtained. The tongue can be bent by any suitable tool.

Figures 3 and 4 show a configuration for adjusting the coupling between the resonators. The reference numerals are the same as in Figures 1 and 2, where applicable. Parallel pairs of slots are cut into the cover wall 10, so that bendable tab or tongue-like portions 11_1 - 11_6 are formed between them. The Figure 3 differs from figure 1 in that the tongues 11_1 - 11_6 of the cover surface 10 are formed so, that after fastening the cover 2 they are located between the resonator holes. Then bending them will affect the capacitive field between the resonators and thus have an effect on the coupling between the resonators, even if the main part of the coupling is effected inductively through the dielectric material. It is possible to form tongues in the wall 9 of the cover 2 also at such locations that will be close to the wall 5 between the resonator holes. Bending these tongues 12_1 - 12_6 will affect also the capacitive coupling between the resonators, although the effect is less than by tongues close to the filter top surface. The tongues may be slightly bent before the cover is fastened, providing allowance for adjustment in both directions.

Figure 4 shows the operation of the tongues in figure 3 when the cover 2 is fastened to the ceramic block. The figure shows a section along line IV - IV of figure 3. The coupling between resonators 6_5 and 6_6 can be affected by bending the tongue 11_5 in the capacitive field between them, either downwards increasing the coupling, or upwards decreasing the coupling. Corresponding adjustment is made at the tongue 12_5, the bending of which also affects the field. In this way it is possible to tune the frequency band of the filter when it is connected to a measuring equipment, so that the filter's characteristic curve and the desired characteristic are simultaneously observed on the equipment screen, and the coupling between the resonators is adjusted by bending the tongues until the frequency band is acceptable. The tongue can be bent by any suitable tool.

The above described adjustment of the resonator frequencies and the coupling between them can also be combined in the same resonator. Then the filter cover 10 will have cuts in quite many places, but by the design of suitable cutting forms it is possible to retain a sufficient stiffness of the cover 10, so that it will remain rigid and stable during tuning.

In view of the foregoing description it will be evident that various modifications may be made within the scope of the invention. For example, the tongues could be made in many ways. Any suitable form of cut can be used instead of the presented cuts with U-form or II-form, provided that a tongue is obtained that can be bent towards and away from the dielectric block. The coupling between the resonators may be adjusted only at the sides, if the side surface is uncoated, or only at the top. It is also possible to use both methods in the same filter. The filter may include only a possibility to adjust the resonance frequency, or to adjust the coupling, or both. Tongues made by cutting are preferably located in the filter metal housing, but it is also possible to use another part which is not fastened to the filter. Such a part could be a suitable conductive surface in the assembled radio equipment, suitably close to the dielectric block, whereby the cuttings can be made in this surface. Then the filter may be manufactured without a housing. Finally it is noted that a filter in accordance with the invention may be a duplex filter for use in such a radiotelephone where the pass-band filters of the transmitter and the receiver may be enclosed in the same housing.

Claims

1. A filter comprising a dielectric block (1) with top, bottom and side surfaces, and having at least one hole extending from the top surface to the bottom surface, the interior surface of said hole(s) and the surfaces of the block being substantially covered, with the exception of at least a part of the top surface (3) and/or one side surface (5), with conductive material (4) in order to provide a transmission line resonator at each hole, electrode means being present on the upper surface and/or on said one side surface for providing electrical signal coupling to the resonators, characterised in that an electrically conductive member (9 and/or 10) is disposed adjacent the top surface (3) and/or said one side surface of the block, said electrically conductive member having at least one cut-out portion (7_1-7_7;11_1-11_7;12_1-12_7) which can be bent towards and away from the block to adjust the tuning of at least one of the resonators.

2. A filter as claimed in claim 1, wherein the electrically conductive member (10) is disposed adjacent the top surface (3) of the dielectric block (1), and the electrically conductive member (10) has a respective bendable cut-out portion (7_1,7_7) located over each resonator hole (6_1-6_7).

3. A filter as claimed in claim 1, wherein the electrically conductive member (10) is disposed adjacent the top surface of the dielectric block (1), and the electrically conductive member (10) has a respective bendable cut-out portion located between neighbouring resonator holes.

4. A filter as claimed in any of the preceding claims, wherein the electrically conductive member (1) is disposed adjacent said one side surface (5) of the dielectric block (1), and the electrically conductive member (9) has a respective bendable cut-out portion (12_1-12_7) located in line with each resonator hole (6_1-6_7).

5. A filter as claimed in any of claims 1 to 3, wherein the electrically conductive member (9) is disposed adjacent said one side surface (5) of the dielectric block (1), and the electrically conductive member (9) has a respective bendable cut-out portion (12_1-12_7) located opposite an area between adjacent resonators.

6. A filter as claimed in any of the preceding claims, wherein the electrically conductive member includes at least one bent side face which is fastened to the dielectric block (1).

7. A filter as claimed in any of the preceding claims, wherein the electrically conductive member is disposed in substantially parallel relationship to the top surface and/or said one side surface.

8. A filter as claimed in any of the preceding claims, wherein the electrically conductive member comprises a portion disposed adjacent the top surface of the dielectric block, and a portion disposed adjacent said one side surface of the dielectric block.

9. A filter as claimed in any of the preceding claims, wherein the electrically conductive member is in the form of a cover made by cutting and bending a unitary metal pre-form.

10. A filter as claimed in any of the preceding claims, wherein the electrically conductive member is provided with spacing members which bear against the dielectric block to define a predetermined spacing between the electrically conductive member and the dielectric block.

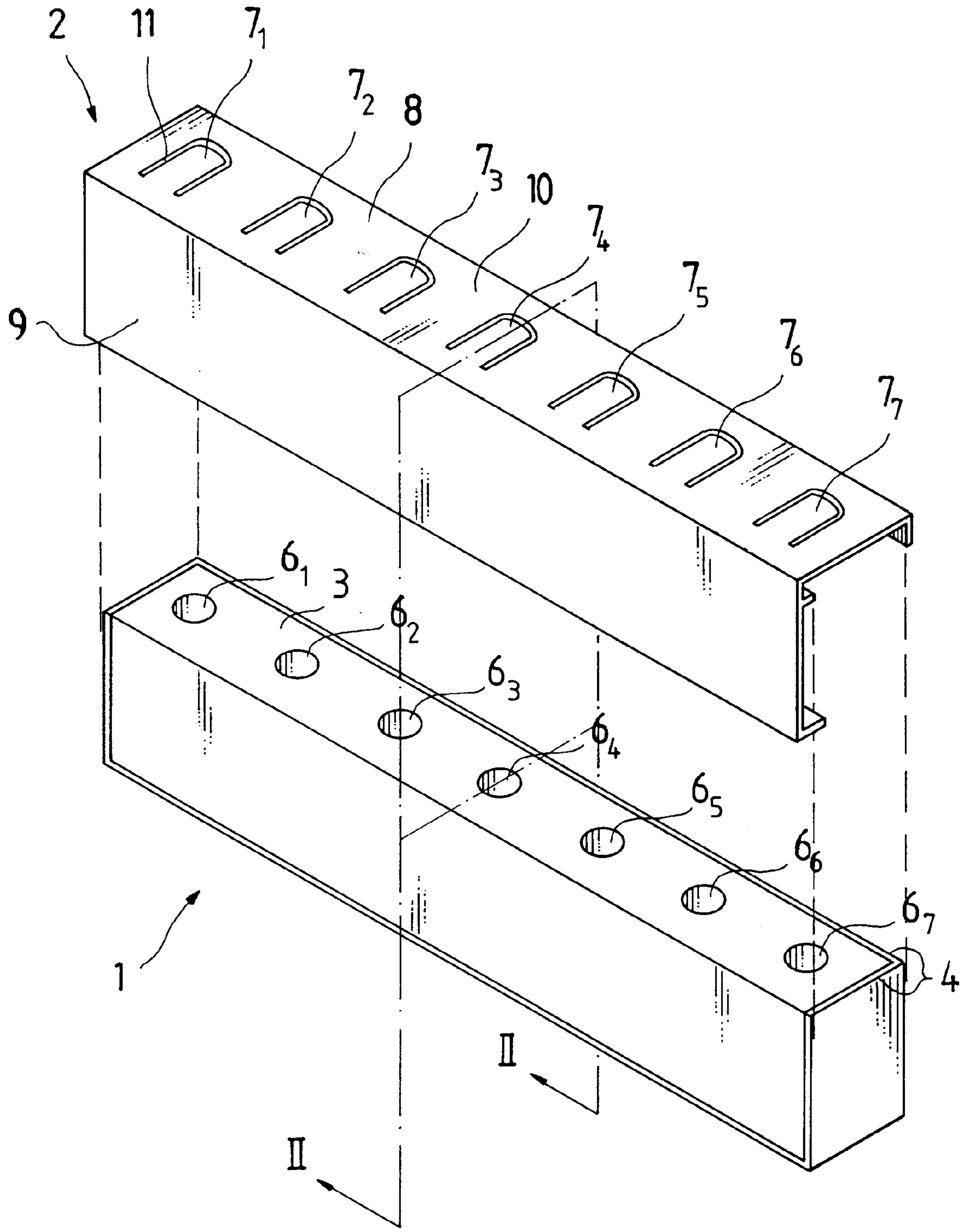


Fig.1

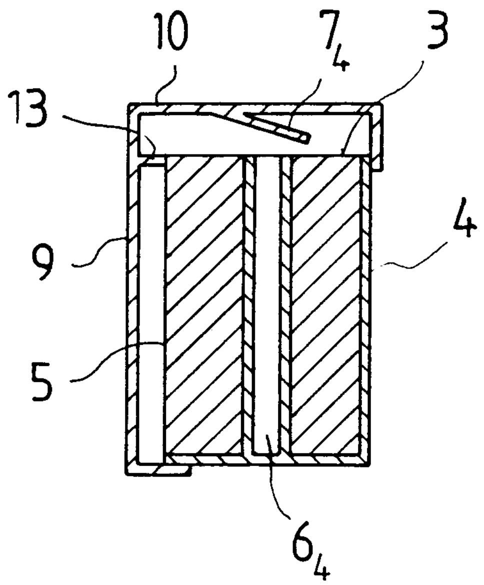


Fig. 2

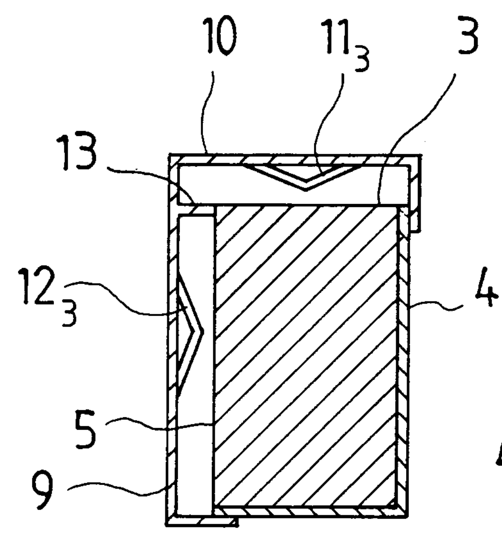
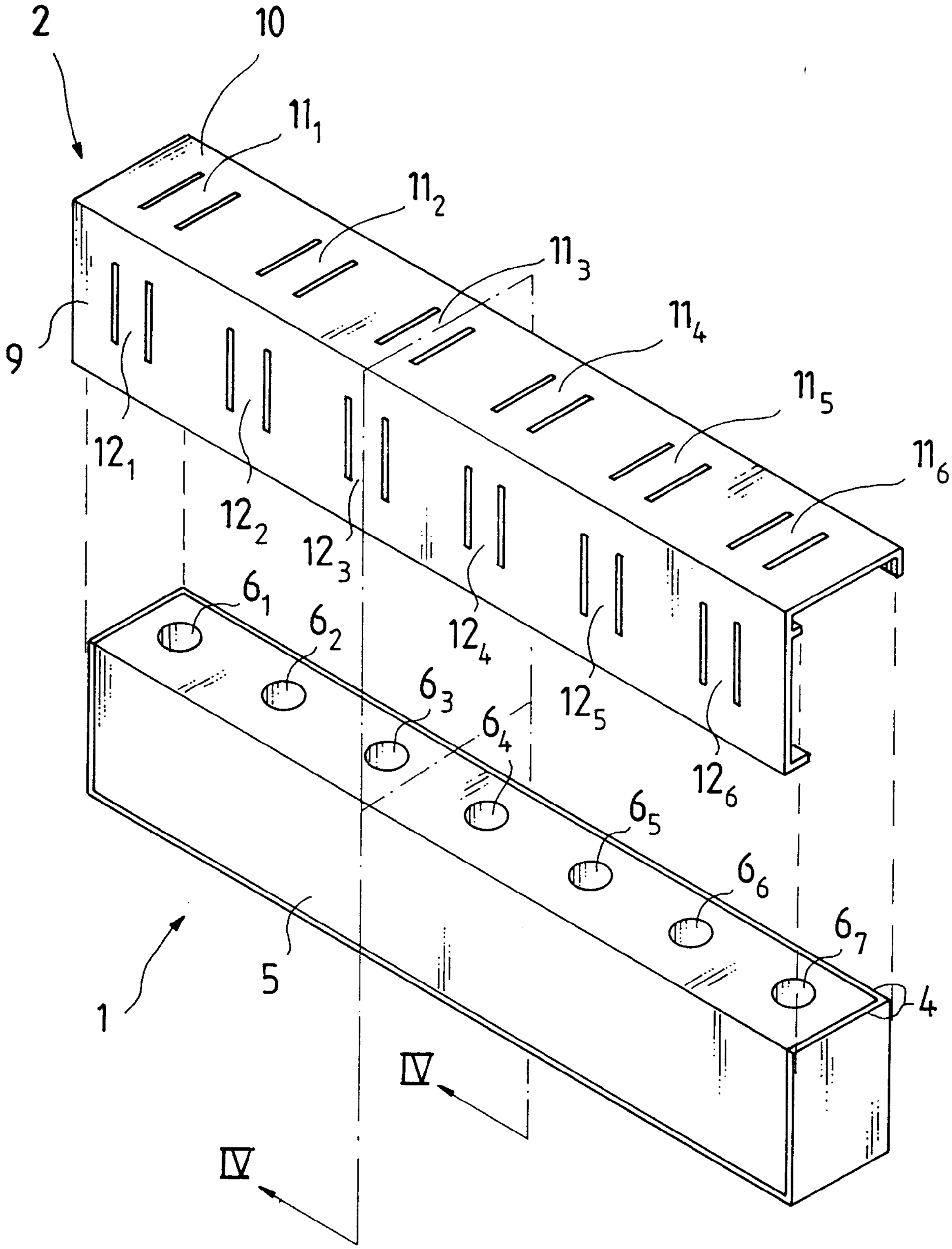


Fig. 4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11_3
11_4
11_5
11_6
9
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12_5
12_6
6_1
6_2
6_3
6_4
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6_6
6_7
4
5
1
IV
IV

Fig.3