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(54) **RADIOFREQUENCY FILTER**

(57) Apparatus comprising a radiofrequency filter (40) is disclosed, which comprises an elongate electrical conductor (33) having a meandering shape from which extends one or more electrically conductive stub elements (47) which acts as a resonator. The stub element has a wider cross-sectional profile than a cross-sectional area of the electrical conductor. In another embodiment, the stubs elements partially encircle the meandering conductor. Also disclosed is a method of manufacture of such a radiofrequency filter using a sheet-like conductive material.

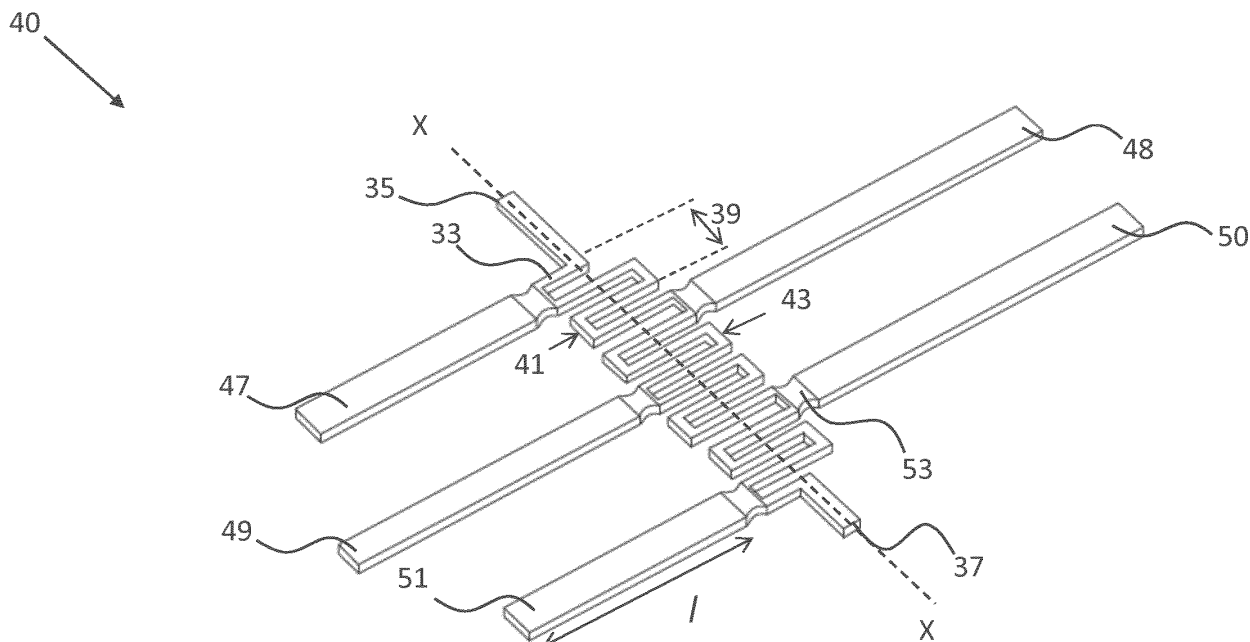


Fig. 3(a)

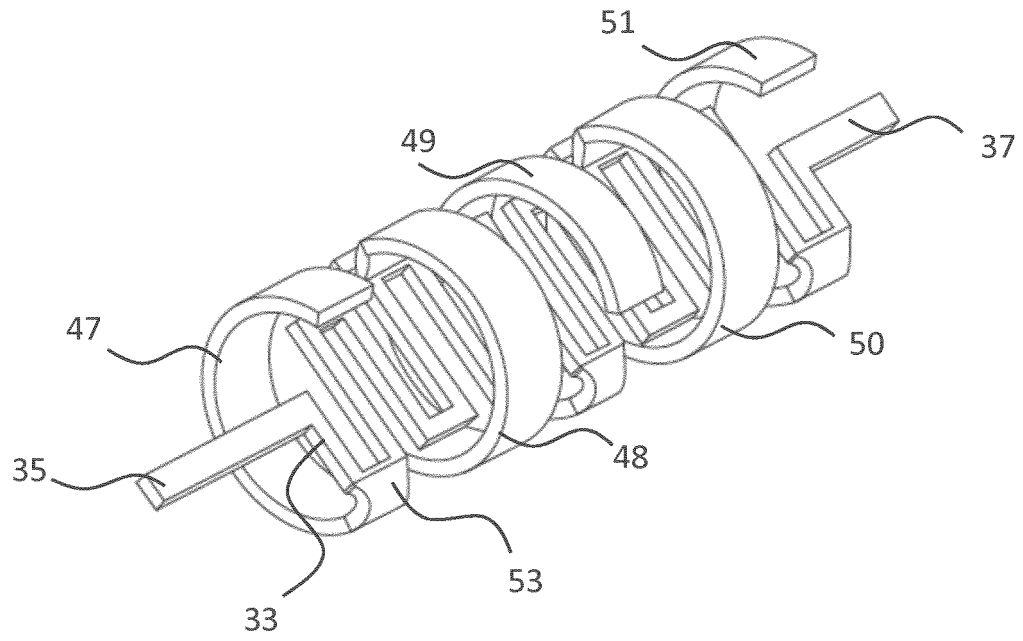


Fig. 5

Description

Field of the Invention

[0001] The present disclosure relates to a radiofrequency (RF) filter and a method of manufacture thereof.

Background of the Invention

[0002] Filters are important components in many electrical systems. In general terms, filters are signal processing circuits or functions for removing unwanted frequency components. A stopband refers to the range of frequencies which are rejected or attenuated, and a passband refers to the range of frequencies that are allowed. A low-pass filter is one which presents less attenuation to low-frequency signals than highfrequency signals. A high-pass filter presents less attenuation to high frequency signals than low frequency signals.

[0003] In the field of mobile communication networks, base transceiver stations (BTS) use RF filters for reducing interference by rejecting out-of-band signals that may interfere with transmission and/or reception. For example, a low-pass RF filter is commonly used in BTS filter units for removing or attenuating harmonic interference signals from the stopband.

[0004] In order to achieve a desired performance, the filters used in BTS filter units may be relatively bulky, expensive and require significant space.

Summary of the Invention

[0005] A first aspect of the present disclosure provides an apparatus comprising a radiofrequency filter which comprises: an elongate electrical conductor having first and second terminals; and an electrically conductive stub element, connected at one part thereof to the electrical conductor, and extending generally away therefrom, the stub element having a greater cross-sectional area than that of a cross-sectional area of the electrical conductor.

[0006] The radiofrequency filter may comprise a plurality of stub elements, each connected at one part thereof to the electrical conductor at respective spaced-apart locations along its length.

[0007] The stub element may provide a resonator arranged to resonate at a frequency determined by the dimensions of the resonator. Where two or more stub elements are provided, each resonates at a respective frequency.

[0008] The electrical conductor may have a meandering shape.

[0009] The electrical conductor may meander either side of a first axis and the stub element may be connected at one part thereof to the electrical element and may extend generally away from the first axis.

[0010] The stub element may extend generally transverse to the first axis.

[0011] Where two or more stub elements are provided,

adjacent stub elements may extend away from the first axis in substantially opposite directions.

[0012] The electrical conductor may meander either side of a first axis and the stub element may be connected at one part thereof to the electrical conductor and shaped so as to at least partly surround the first axis.

[0013] The stub element may be shaped so as to at least partly encircle the first axis.

[0014] The stub element may be connected at one part thereof to the electrical conductor by a portion having a smaller cross-sectional area relative to a cross-sectional area of the stub-element to permit bending of the or each stub element relative to the electrical conductor.

[0015] The electrical conductor may have one of a generally sinuous, square-wave or zig-zag shape, and the stub element may be connected to the electrical conductor substantially at a region of maximum amplitude.

[0016] The electrical conductor and the stub element may be integrally formed from a single sheet of electrically conductive material.

[0017] The stub element may be shaped so as to have one or more of a generally rectangular shape, L shape or U shape.

[0018] The apparatus may further comprise a bridging member attached to the stub element such that said stub element completely surrounds the first axis.

[0019] A second aspect of the present disclosure provides an apparatus comprising: a filter chassis comprising a body having one or more apertures or recesses formed therein; and

one or more filters, according to any preceding definition, located within one or more respective apertures or recesses of the filter chassis.

[0020] The filter chassis may be formed of a metal or metal-plated material and a dielectric provided between the one or more filters and the filter chassis.

[0021] A third aspect of the present disclosure provides a method, comprising: providing a radiofrequency filter by the steps of: providing an elongate electrical conductor having first and second terminals; and providing an electrically conductive stub element connected at one part thereof to the electrical conductor along its length, and extending generally away therefrom, the stub element having a greater cross-sectional area than that of the electrical conductor.

[0022] The method may further comprise providing two or more electrically conductive stub elements.

[0023] The method may further comprise integrally forming the electrical conductor and the stub element from a single sheet of electrically conductive material.

[0024] The method may further comprise shaping the stub element so that it at least partially encircles the electrical conductor. Alternatively, the stub element may be shaped so as to be a generally rectangular shape, L shape or U shape.

Brief Introduction to the Drawings

[0025] The present disclosure will now be described, by way of non-limiting example, with reference to the drawings in which:

Figure 1 is a schematic diagram of a cellular base station, including a base transceiver station;
 Figure 2 is a partial perspective view of a filter unit chassis for receiving one or more filters according to embodiments;
 Figures 3a and 3b are perspective and top plan views of a filter blank in accordance with an embodiment of the present disclosure;
 Figure 4 is a top plan view of a sheet of electrically conductive material from which one or more filter blanks may be formed;
 Figure 5 is a perspective view of an operational filter resulting from bending the blank shown in Figures 3a and 3b;
 Figure 6 is an alternative view of the Figure 5 filter;
 Figures 7a and 7b are graphs of simulated results for comparing the respective performance of a conventional filter and the Figure 5 filter;
 Figure 8 is a flowchart showing examples of operations for providing a filter unit which comprises the Figure 5 operational filter;
 Figures 9a and 9b are cross-sectional views of different parts of the Figure 4 filter blank;
 Figure 10 is a cross-sectional view of the Figure 5 filter when located within a filter unit chassis;
 Figure 11 is a perspective view of the Figure 5 filter when located within a horizontal groove of a filter unit chassis; and
 Figures 12a - 12d are perspective views of respective, alternative filter embodiments.

Detailed Description of Embodiments

[0026] Embodiments described herein relate to RF filters, RF filter units and methods of manufacture of RF filters.

[0027] Embodiments particularly, though not exclusively, relate to RF filters for use in base transceiver stations (BTS) of mobile communications networks.

[0028] Growth in the mobile telecommunications industry has brought about advances in filter technology as new communications systems emerge, requiring more stringent filter characteristics. In the field of mobile communications, filter miniaturization has been responsible for many advances.

[0029] Figure 1 shows a simplified cellular BTS 1 which may be part of, or associated with, an antenna tower 3 carrying one or more RF antennas 5 in signal communication with the BTS 1 using one or more conductors 7. The BTS 1 is usually housed in an enclosure located at or near the base of the antenna tower 3. The BTS 1 is in signal communication with a backhaul communications

system 11 which provides intermediate links to a core network. Within the BTS 1 are provided various analogue and digital signal processing modules. For example, one or more RF filter units 9 may be provided.

[0030] A plurality of RF filter units 9 may be provided, serving different purposes. These may be low-pass, high-pass and/or band-pass filter units.

[0031] For example, a RF filter unit 9 may comprise one or more low-pass filters for removing or attenuating spurious signals from the stopband. Such spurious signals may, for example, result from harmonic interference. A RF filter unit 9 may comprise an enclosure housing one or more filters.

[0032] Figure 2 is a partial perspective view of a filter unit chassis 35 which may be situated in a filter unit enclosure. The chassis 35 may comprise an electrically conductive material, such as metal or metal plated dielectric material. The chassis 35 provides a plurality of apertures or recesses for locating separate parts to make a filter assembly, which acts as a transmission line in a selected frequency range. One part of that transmission line is a low-pass filter. A low pass filter may be provided in a groove, hole or other shape depending on selected design.

[0033] Embodiments herein provide a low-pass filter which is simple and cost-effective to manufacture, is small in size and which can achieve a desired response in a relatively small area or volume. The low-pass filter may be part of the signal transmission line and therefore needs to be insulated from the filter ground by dielectric material.

[0034] Embodiments herein provide a filter, such as a low-pass filter, which may be formed from a substantially planar or sheet-like form of conductive material to provide a blank for subsequent shaping. For example, metal material may be used. The metal material may be copper or aluminium, for example. Any known manufacturing method for removing a blank from sheet material may be employed for this purpose. For example, pressing, mechanical cutting and/ or laser cutting may be employed. The sheet material may be a single sheet, or multiple sheets may be employed.

[0035] Referring to Figures 3a and 3b, a low-pass RF filter (hereafter "LPF") 40 according to a first embodiment is shown. More specifically, the LPF 40 is shown in the form of a blank, subsequent to its pressing/ cutting from a sheet of conductive material. The subsequent shaping stage for realising the operational filter will be described later on. For ease of explanation, we will refer to both the blank and operational forms as the LPF 40. It will be appreciated that the stages of forming the blank and operational forms of the LPF 40 may be performed separately, and at separate manufacturing locations.

[0036] The LPF 40 comprises an elongate electrical conductor 33 which extends in a planar, meandering form from a first terminal 35 to a second terminal 37. A meandering form is a path that follows a winding course, and may, for example, be a zig zag path, a sinusoidal path,

or square wave path or the like. The shape of the first and second terminals 35, 37 can be designed as per assembly requirements. The electrical conductor 33 meanders either side of a lengthwise axis X-X. For example, the meandering electrical conductor 33 may extend lengthwise in a square-wave pattern. The width and/ or cross-sectional profile of the electrical conductor 33 may be substantially constant along its length.

[0037] The electrical conductor 33 may be formed of any suitable conductive material, for example a metal material such as copper or aluminium.

[0038] The first and second terminals 35, 37 may be continuations of the electrical conductor 33. The first and second terminals 35, 37 may be situated opposite one another, for example situated substantially on the lengthwise axis X-X. Each of the first and second terminals 35, 37 may be used to connect the LPF 40 to external circuitry and/or to connect one LPF to another.

[0039] In other embodiments, the meandering electrical conductor 33 may extend lengthwise in a sinusoidal, zig-zag or saw-tooth pattern.

[0040] Using the analogy of analogue electrical signals, the square-wave (or other) pattern of the meandering electrical conductor 33 may be a repeating pattern. For example, the square-wave may comprise a plurality of repeating cycles or periods 39. Each period 39 may be substantially identical in mechanical terms. Each period 39 may comprise a negative and a positive portion, relative to the lengthwise axis X-X. Each period 39 may have regions or points 41, 43 of maximum negative and positive amplitude.

[0041] The cross-sectional profile of the electrical conductor 33 may be rectangular.

[0042] The LPF 40 may also comprise one or more conductive stub elements 47 - 51. The shown example, and others, employ a plurality of stub elements 47 - 51 but it will be appreciated that only one stub element may be provided (see Figure 12d.)

[0043] As will be appreciated, a stub element in mechanical terms is an arm having a connected end and a free end. Each stub element 47 - 51 is generally elongate in form and connected at one end thereof to the electrical conductor 33 at respective locations along, or relative to, the lengthwise axis X-X. For example, the adjacent stub elements 47 - 51 may be spaced apart along, or relative to, the lengthwise axis X-X, i.e. not touching one another. Each stub element 47 - 51 may be substantially rectangular in form, i.e. having rectangular major and minor faces. The cross-sectional shape of the stub elements 47 - 51 may be substantially rectangular.

In some embodiments, the stub elements 47 - 51 are arranged such that they extend away from the lengthwise axis X-X, for example substantially perpendicular to said axis. In some embodiments, adjacent stub elements 47 - 51 may extend in different orientations, for example opposite negative and positive orientations as shown, on substantially the same plane. Where more than two stub elements 47 - 51 are provided, there may be an alternat-

ing left-right arrangement of stub elements.

[0044] Each stub element 47 - 51 may be connected to a different, spaced-apart portion of the electrical conductor 33 at points or regions of maximum amplitude.

[0045] The spacing between adjacent ones of the stub elements 47 - 51 may be equal to 1.5 periods (in mechanical terms) of the meandering electrical conductor 33. For example, the first stub element 47 may be connected to the first, negative portion of the meandering electrical conductor 33, and the second stub element 48 may be connected to the next-but-one positive portion of the meandering electrical conductor, and so on. The effect of the spacings may be simulated to confirm the required band stop effect in a selected frequency range. The length of the electrical conductor 33 can be adjusted to determine the location of a rejection notch in the stop band.

[0046] Each stub element 47 - 51 may be connected to their respective portions of the meandering electrical conductor 33 by means of a region 53 of relative weakness. This region 53 may be formed with a narrowing widthways profile, for example by forming the lateral edges with an arcuate shape. This is to permit bending of the stub elements 47 - 51 relative to the meandering electrical conductor 33 in forming the operational LPF 40.

[0047] Each stub element 47 - 51 is produced in such a way as to have a lower electrical resistance, or impedance at frequencies of interest, than that of the meandering electrical conductor 33. In some embodiments, this is by virtue of the different dimensions used for the meandering electrical conductor 33 and the stub elements 47 - 51. In particular, the meandering electrical conductor 33 may have a smaller cross-sectional area than that of each of the stub elements 47 - 51 and hence has higher impedance at frequencies of interest.

[0048] Each stub element 47 - 51 is arranged to act as a respective low-impedance resonator at RF frequencies. The resonant frequency associated with each stub element 47 - 51 is determined by its respective dimensions. For ease of manufacture, the resonant frequency for a respective stub element 47 - 51 is substantially determined by its length l which is significantly larger than its width or thickness. During manufacture, the stub elements 47 - 51 are formed with a length appropriate for the required filter response, i.e. to attenuate spurious interference.

[0049] Referring to Figure 4, one or more blanks corresponding to the LPF 40 may be pressed or cut from a sheet 60 of conductive material, for example metal material. Cutting may be by means of mechanical or laser cutting, for example. The lengths l of the stub elements 47 - 51 may be calculated in advance based on required frequency characteristics, and entered into, for example, a Computer Numerical Control (CNC) cutting system. The process is therefore straightforward, relatively inexpensive and can produce LPFs 40 in large numbers.

[0050] In a subsequent stage, the blank form of LPF 40 is modified to assume an operational shape.

[0051] With reference to Figures 5 and 6, each of the stub elements 47 - 51 are deformed such that they assume a curvilinear shape to partially surround or encircle the meandering electrical conductor 33. The curvilinear shape may or may not follow a perfectly circular shape. A gap may be left between the curvilinear part of each stub element 47 - 51 and the meandering electrical conductor. In another embodiment, a cap (not shown) may be placed at the distal end of one or more stub elements 47 - 51 and attached to the other end of the stub element, for example by welding, laser welding, soldering or similar, to provide one or more closed loop (e.g. circular) resonators. Deformation, or bending, of the stub elements 47 - 51 is assisted by means of the region 53 of relative weakness at the interface with the meandering electrical conductor 33.

[0052] The spacing between the stub elements 47 - 51 avoids or reduces potential interference between adjacent elements.

[0053] In some embodiments, different configuration of the stub elements 47 - 51 gives different filter response, and so so it might be necessary to have different configurations for different frequency response variants. For example, in some embodiments, all left or all right-handed stubs may be provided, instead of the alternate left and right handed stubs, or all closed circular loops may be used, left of right handed. Also, any combination of above-mentioned configurations can be used.

[0054] The curvilinear shape of the stub elements 47 - 51 may be achieved using known manufacturing methods for bending metal.

[0055] The overall operational shape of the LPF 40 generally resembles a cylinder. Provided that the radii of the stub elements 47 - 51 are substantially the same, the diameter of the LPF 40 will be substantially constant along its operational length L.

[0056] Other shapes may be employed, for example based on the shape of the filter chassis groove or hole for the LPF 40. The shape of LPF 40, for example, may be cylindrical, square, L-shaped, U-shaped, or similar. The stub elements 47 - 51 may have a relatively small distance to the filter ground level. The distance may be controlled by using dielectric material between the stub elements 47 - 51 and ground.

[0057] The cylindrical shape of the LPF 40 permits it to be located in a tubular aperture or recess 37 of a filter unit chassis 35, for example as shown in Figure 2. If needed, multiple LPFs which are the same or similar in general structure as LPF 40 may be connected in series. The LPF 40 may therefore provide a useful replacement for tubular filters. The LPF 40 may alternatively have a different shape to locate within a corresponding shaped hole or groove.

[0058] Figures 7a and 7b show simulated results for comparing the respective performance of a conventional filter and the LPF 40 described above. It will be seen from Figure 9b that the response of the LPF 40 is sharper (which can be aligned closely to a separate band-pass

filter) and exhibits an almost bandstop effect. Furthermore, attenuation notches 91, 93, 95 (zeros) in the pass-band result from the resonant frequencies of the stub elements 47 - 51 which can be designed / tuned to remove spurious interference. The lighter curves represent return loss.

[0059] Referring to Figure 8, there is shown a flowchart showing examples of operations for providing a filter unit using one or more LPFs 40 described above. A first operation s10.1 may comprise designing the one or more LPFs 40, for example to determine the required lengths / of the stub elements 47 - 51 to meet a required frequency response. Operation s10.1 may also comprise determining the required number of stub elements 47 - 51. Other dimensions may also be determined. Computer Aided Design (CAD) software may be used for this purpose.

[0060] Operations 10.2 and 10.3 relate to the manufacturing method. Operation 10.2 comprises forming one or more filter blanks from sheet material. This operation may be performed automatically by Computer Aided Manufacture (CAM) based on model data generated by the previous operation 10.1. The process is therefore suitable for mass production. Operation 10.3 comprises bending the stub elements 47 - 51 of the filter blank(s) into curvilinear form to provide the operational LPFs 40. Similarly, this operation may be performed automatically by CAM based on model data. Either operation may be performed manually, however. Operations 10.2 and 10.3 may be performed at distinct, separate times and at separate locations.

[0061] Operation 10.4 comprises locating the one or more LPFs 40 into a chassis or enclosure of a filter unit. Operation 10.4 may be performed manually or automatically.

[0062] Figure 9 shows a LPF 70 according to another embodiment, in blank form. The LPF 70 is similar to the aforementioned LPF 40 but has a substantially straight electrical conductor 75 instead of a meandering one. Stub elements 77 extend away from the electrical conductor 75 in the same general way. The blank form of LPF 70 can be produced and shaped in substantially the same way as the LPF 40.

[0063] Referring to Figures 9a and 9b, the cross-sectional profiles of the Figure 5 electrical conductor 33 and one of the stub elements 47 - 51 are shown respectively. It will be seen that the cross-sectional profile of the electrical conductor 33 is smaller relative to a cross-sectional area of the stub-elements 47 - 51 by virtue of having a smaller width than that of the stub elements. The former therefore has higher impedance than the stub elements 47 - 51. Also, the distance to the ground plane is bigger for the electrical conductor in Figure 10a than the stub elements 47 - 51 in Figure 10b.

[0064] Figures 10 to 12 show alternative LPF structures representing further embodiments.

[0065] For example, Figure 10 is a cross-sectional view of the LPF 40 when located within a chassis 35; an insulating material 60 is located between the ground plane

and the LPF 40. Figure 11 is a perspective view of the LPF 40 within a horizontal chassis groove.

[0066] Figures 12a-d are perspective views of a different LPF structures. Figure 12a shows a LPF 61 with one or more closed-loop stubs, i.e. where a bridging member or cap 62 interconnects the stub subsequent to initial forming. Figure 12b shows a rectangular-shaped LPF 63, for example for locating within a horizontal chassis groove. Figure 12c shows an alternative LPF 64. Figure 12d shows an alternative LPF 65 comprising only one stub element extending from the electrical conductor.

[0067] In overview, an improved filter and method of filter manufacture has been described. Although described in the context of LPFs, it will be appreciated that the structure and method of manufacture may be applied to other types of filter, for example a high-pass filter and a band-stop filter. The resulting filter is easy to produce using standard techniques, is relatively lightweight and inexpensive, and performs comparable / improved performance using a structure that can occupy a smaller volumetric space.

[0068] The described filter may find particular advantages when used as part of a multi-mode filter, for example in association with a ceramic core or other high dielectric constant core.

[0069] Although various aspects of the present disclosure are set out in the independent claims, other aspects of the present disclosure comprise other combinations of features from the described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

[0070] It is also noted herein that whilst the above describes various examples, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which maybe made without departing from the scope of the present disclosure as defined in the appended claims.

Claims

1. Apparatus comprising a radiofrequency filter which comprises:

an elongate electrical conductor having first and second terminals; and
an electrically conductive stub element, connected at one part thereof to the electrical conductor, and extending generally away therefrom, the stub element having a greater cross-sectional area than that of a cross-sectional area of the electrical conductor.

2. The apparatus of claim 1, wherein the radiofrequency filter comprises a plurality of stub elements, each connected at one part thereof to the electrical conductor at respective spaced-apart locations along its

length.

3. The apparatus of claim 1 or claim 2, wherein the stub element provides a resonator arranged to resonate at a frequency determined by the dimensions of the resonator.
4. The apparatus of any preceding claim, wherein the electrical conductor has a meandering shape.
5. The apparatus of claim 4, wherein the electrical conductor meanders either side of a first axis and the stub element is connected at one part thereof to the electrical conductor and extends generally away from the first axis.
6. The apparatus of claim 5, wherein the stub element extends generally transverse to the first axis.
7. The apparatus of claim 4, wherein the electrical conductor meanders either side of a first axis and the stub element is connected at one part thereof to the electrical conductor and shaped so as to at least partly surround the first axis.
8. The apparatus of claim 7, wherein the stub element is shaped so as to at least partly encircle the first axis.
9. The apparatus of any preceding claim, wherein the stub element is connected at one part thereof to the electrical conductor by a portion having a smaller cross-sectional area to permit bending of the stub element relative to the electrical conductor.
10. The apparatus of claim 4 or any claim dependent thereon, wherein the electrical conductor has one of a generally sinuous, square-wave or zig-zag shape, and in which the stub element is connected to the electrical conductor substantially at a region of maximum amplitude of the generally sinuous, square-wave or zig-zag shape.
11. The apparatus of any preceding claim, wherein the electrical conductor and the stub element are integrally formed from a single sheet of electrically conductive material.
12. An apparatus comprising:

a filter chassis comprising a body having one or more apertures or recesses formed therein; and one or more filters, according to any preceding claim, located within one or more respective apertures or recesses of the filter chassis.
13. A method, comprising:

providing a radiofrequency filter by the steps of:

providing an elongate electrical conductor having first and second terminals; and providing an electrically conductive stub element connected at one part thereof to the electrical conductor along its length, and extending generally away therefrom, the stub element having a greater cross-sectional area than that of a cross-sectional area of the electrical conductor.

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- 14.** The method of claim 15, wherein the radiofrequency filter is provided by integrally forming the electrical conductor and the stub element from a single sheet of electrically conductive material.

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- 15.** The method of claim 13 or claim 14, further comprising shaping the stub element so that it at least partially encircles the electrical conductor.

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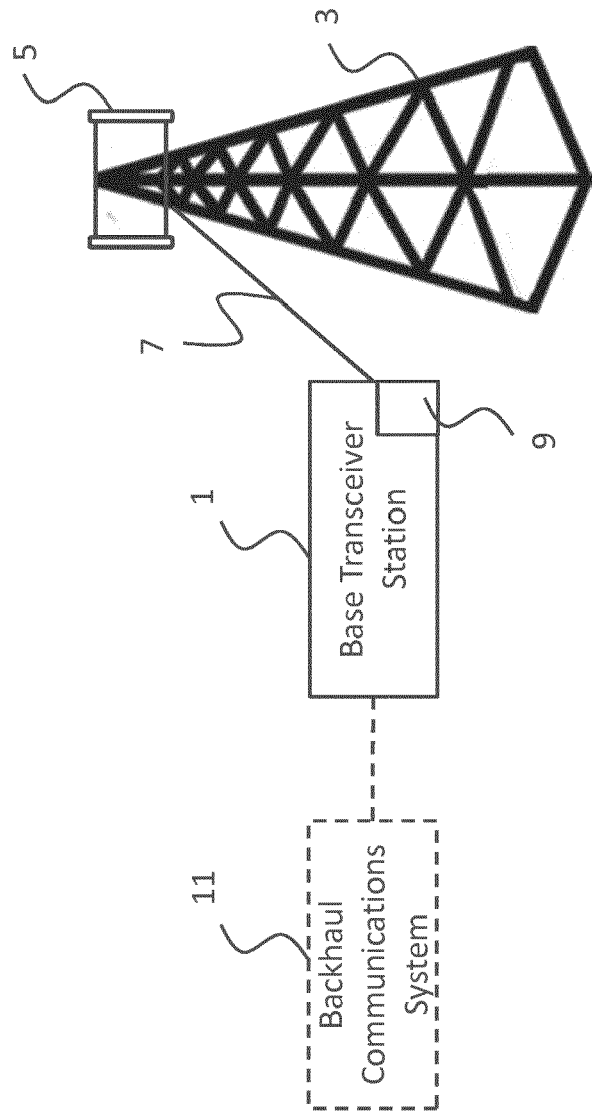


Fig. 1

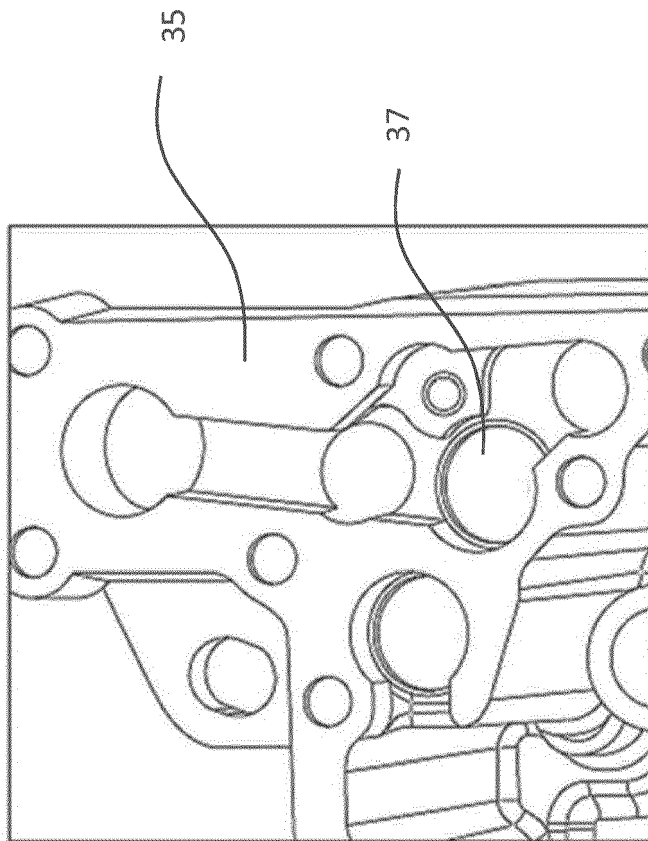


Fig. 2

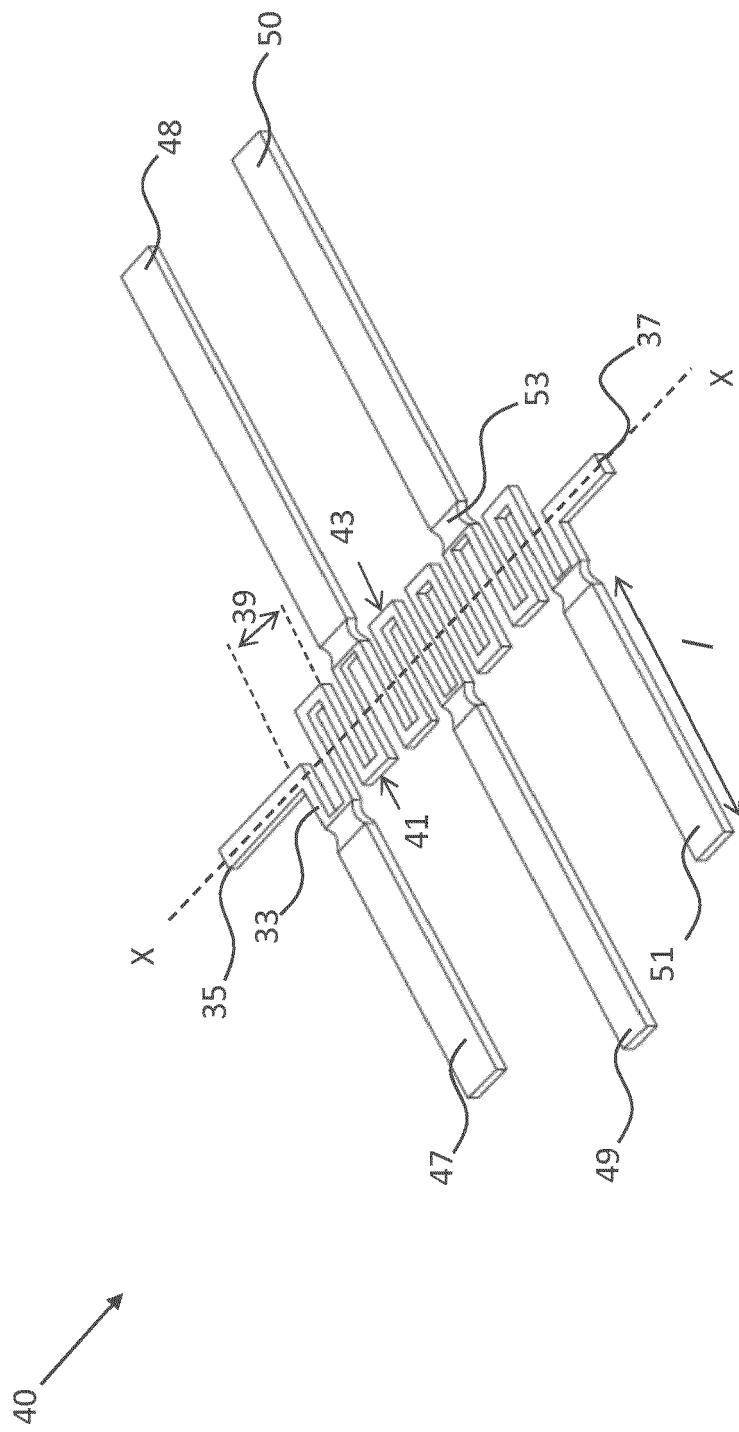


Fig. 3(a)

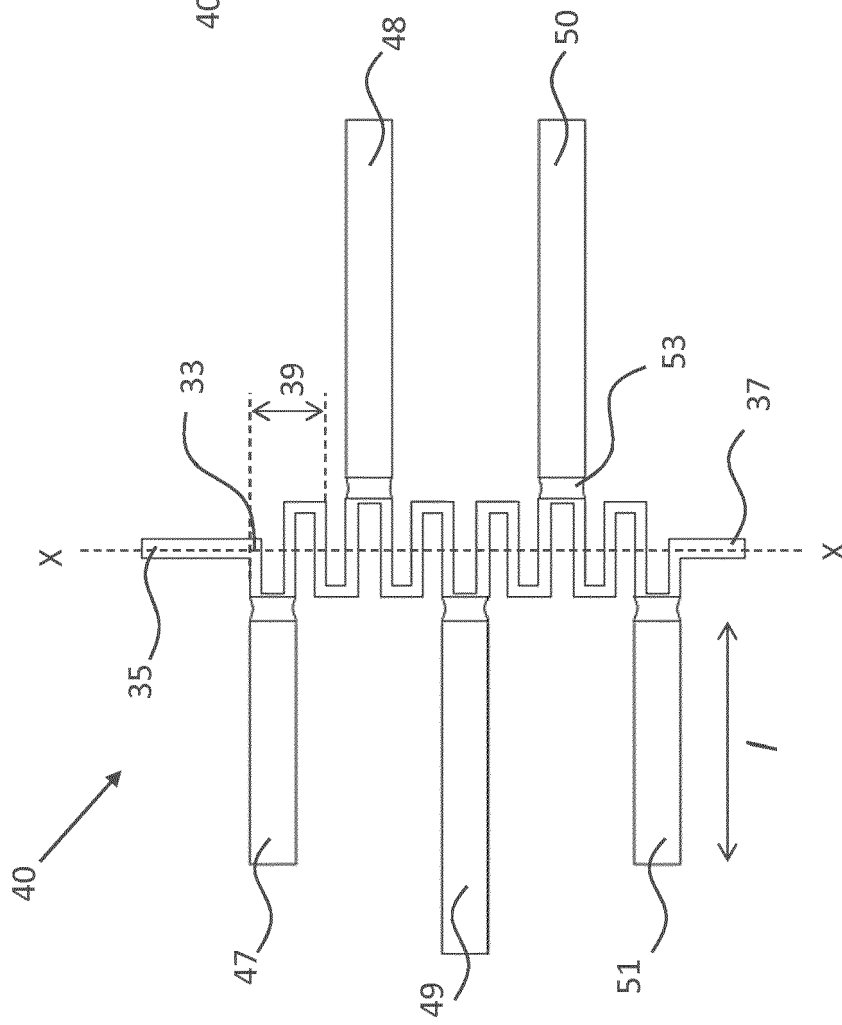


Fig. 3 (b)

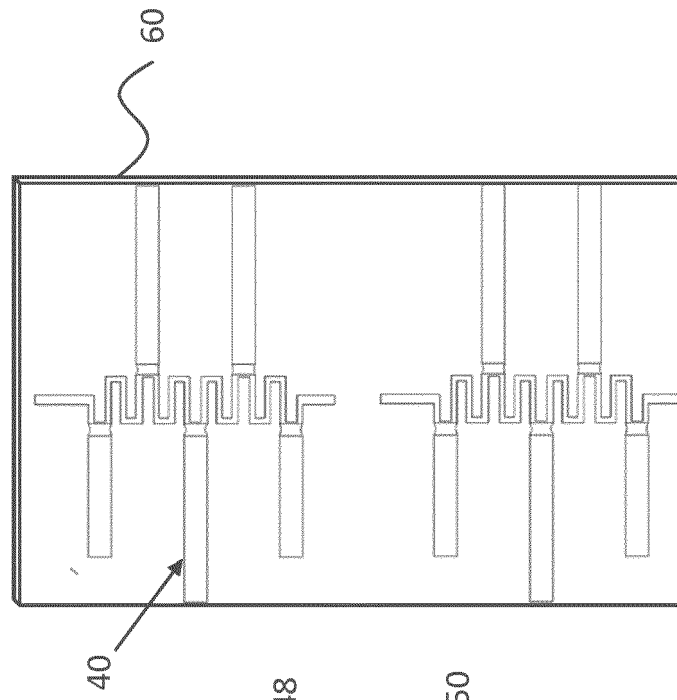


Fig. 4

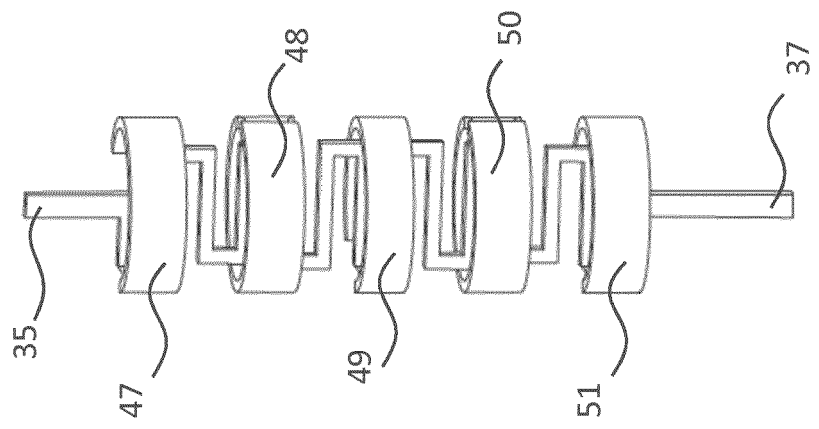


Fig. 6

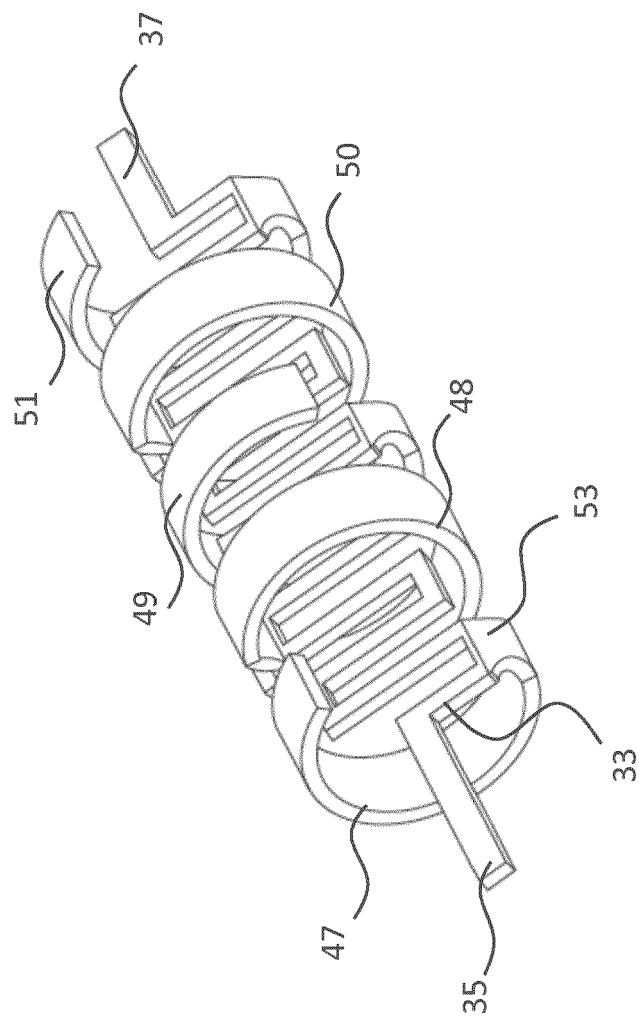


Fig. 5

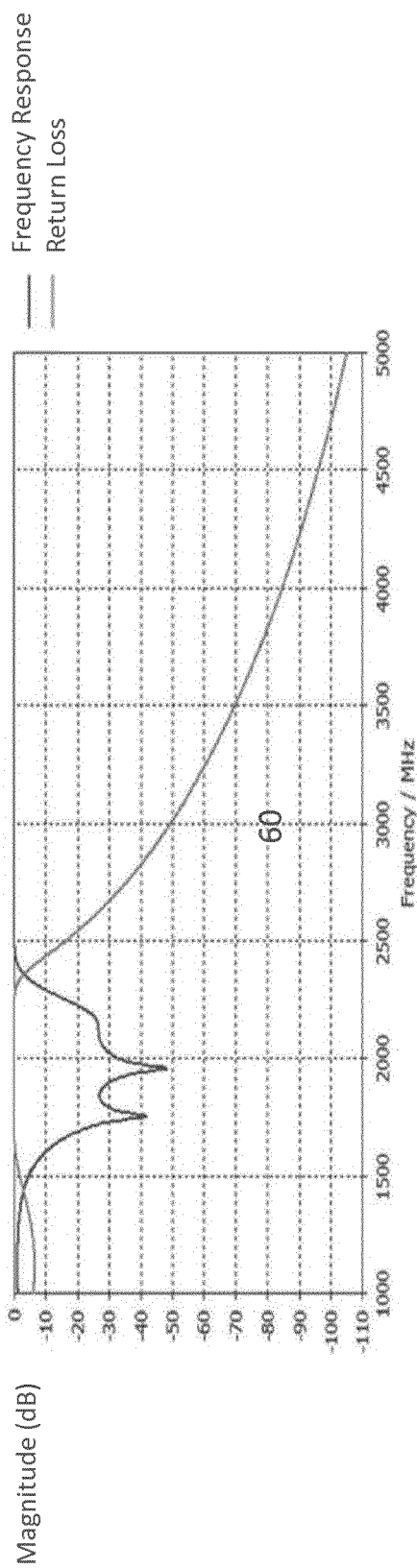
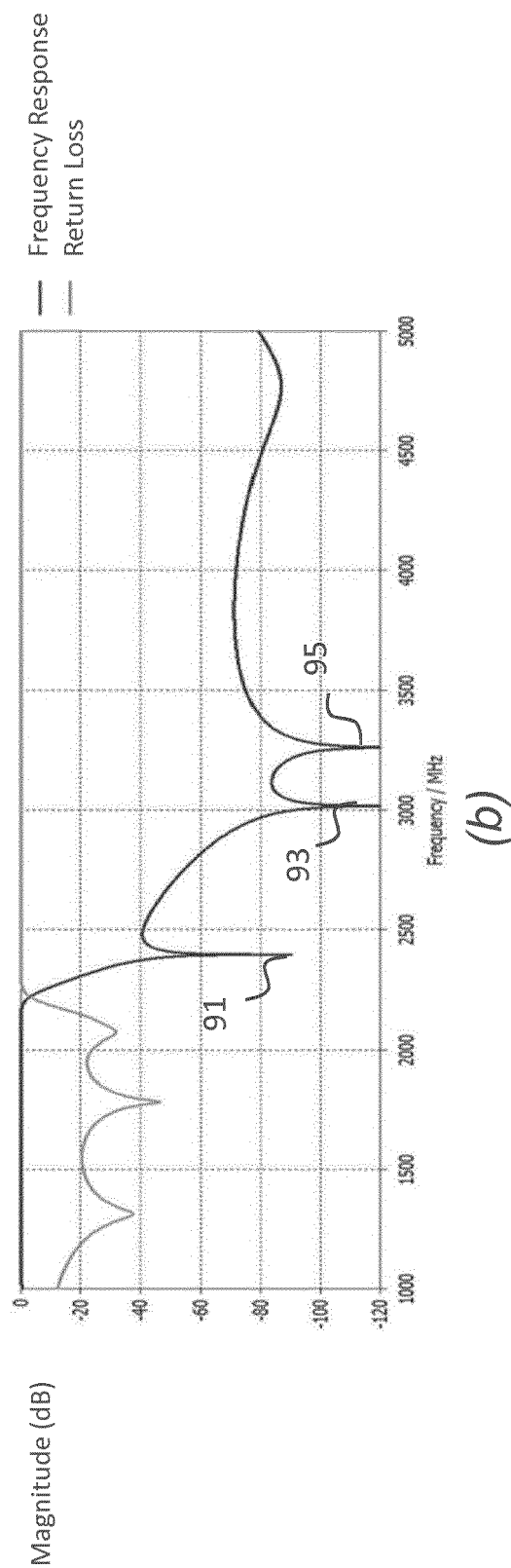


Fig. 7

(a)



(b)

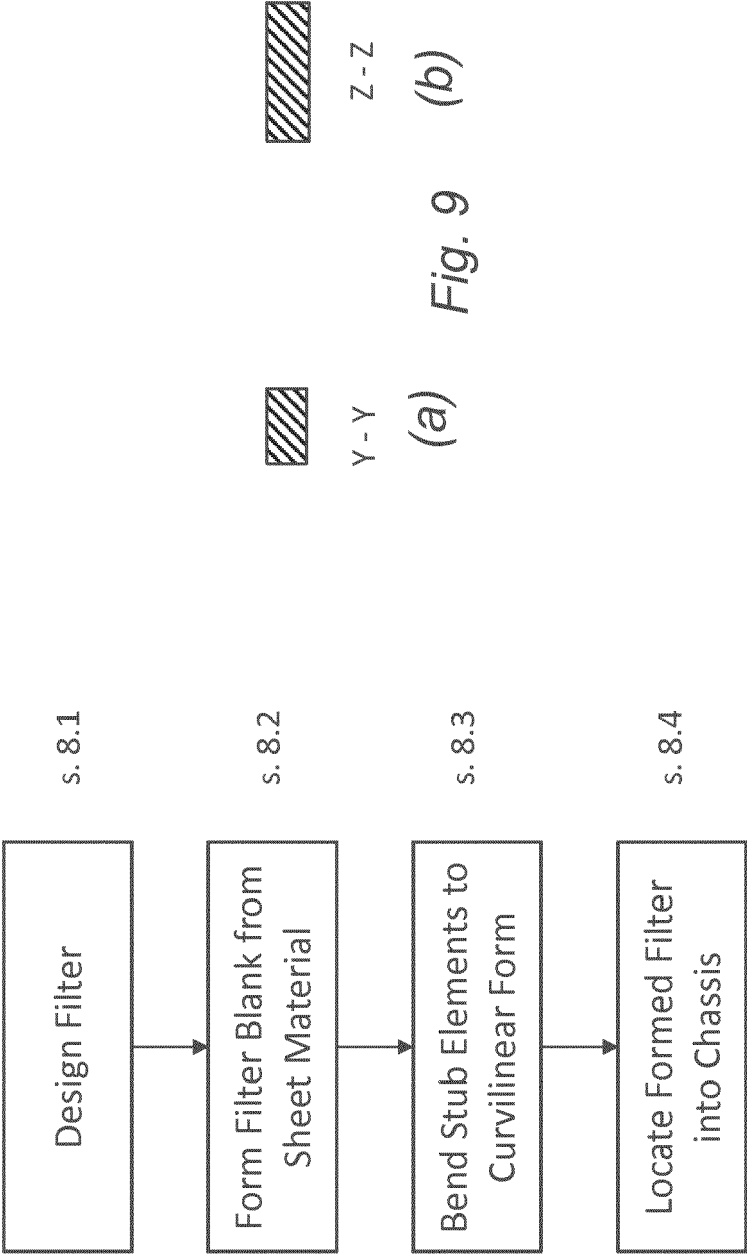


Fig. 8

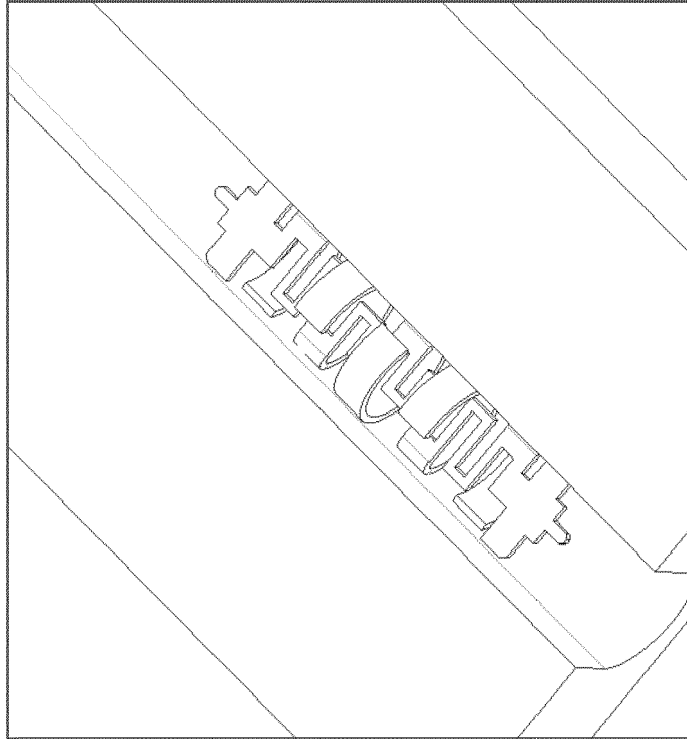


Fig. 11

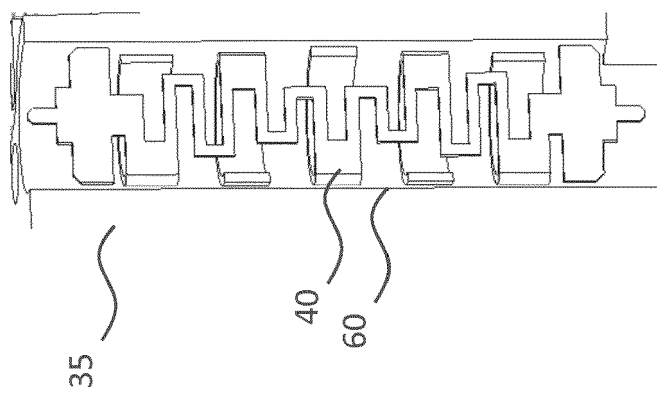


Fig. 10

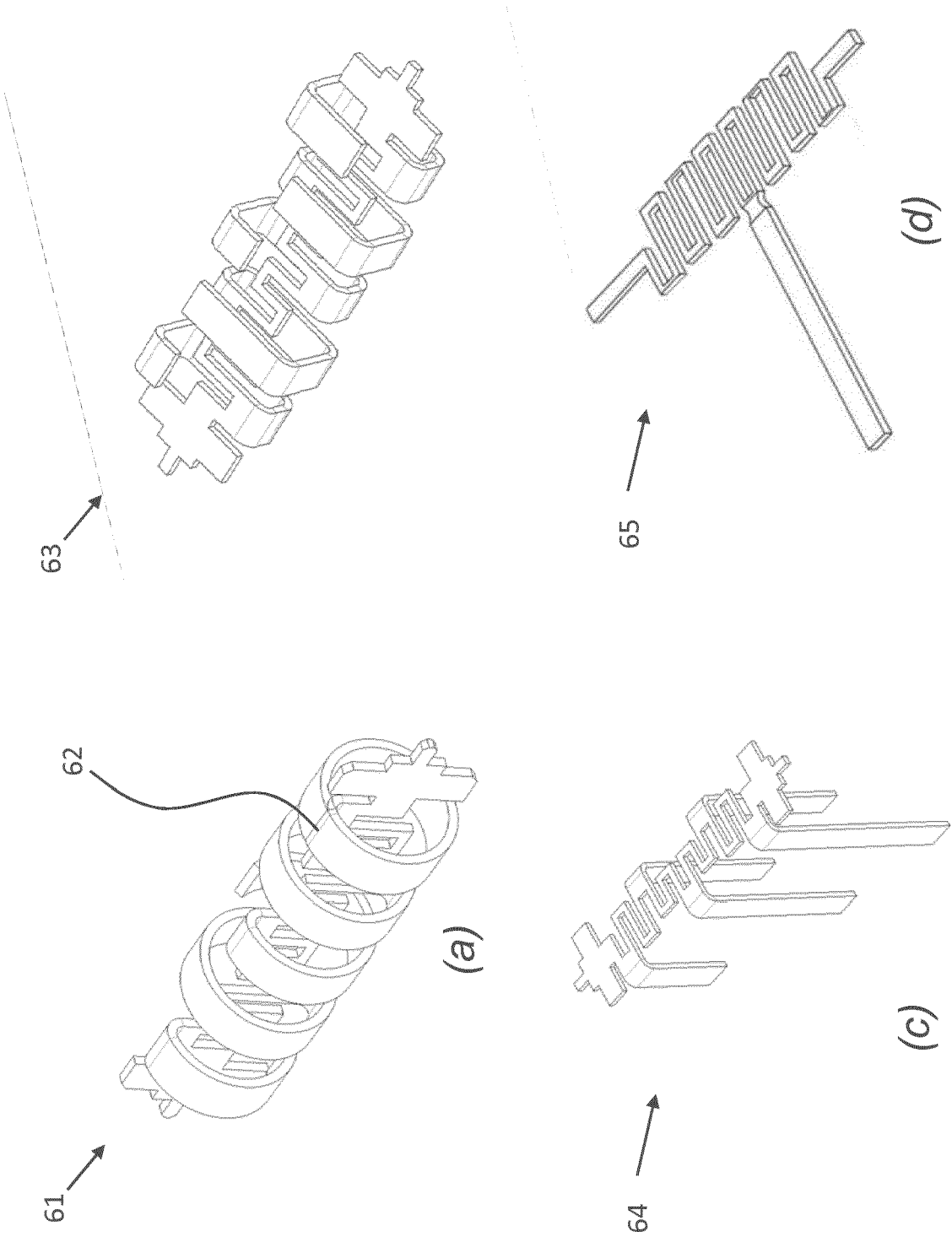


Fig. 12



EUROPEAN SEARCH REPORT

Application Number
EP 17 18 9005

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EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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