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(54) A dielectric TEM mode resonator and a bandstop filter including such a resonator

(57) A dielectric TEM mode resonator (20) comprising
a dielectric core (21) comprising first and second spaced apart faces (22, 23) and a side wall (24) extending therebetween, the first and second faces and side wall together defining an exterior surface (30);
a conduit (27) extending through the dielectric core from an aperture (25) in the first face to an aperture (26) in the second face, the conduit wall defining an interior surface (29);
an electrically conducting coating layer (31), the electrically conducting coating layer extending from the first aperture to at least partially coat the interior surface and at least partially coat the exterior surface, the coating not extending over the exterior surface as far as the second aperture;
an electrically conducting rod (32) at least partially within the conduit; and,
an electrically insulating layer (33) sandwiched between the rod and metal coating on the interior surface such that the rod is not in electrical contact with the electrically conducting coating.

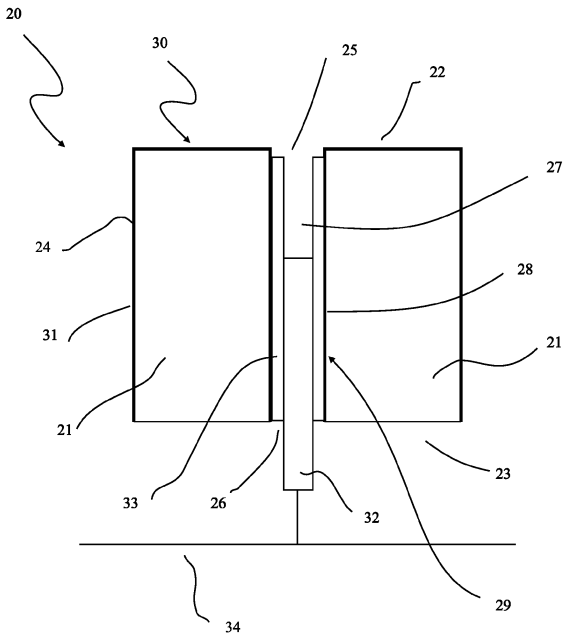

Figure 3

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Description

[0001] The present invention relates to a dielectric TEM mode resonator and a bandstop filter including such a resonator. More particularly, but not exclusively, the present invention relates to a dielectric TEM mode resonator comprising a dielectric core having an electrically conducting coating thereon. A conduit extends through the dielectric core. Arranged within the conduit is a rod. The rod is electrically isolated from the conduit by an insulating layer. More particularly, but not exclusively, in a further aspect the present invention provides a bandstop filter including at least one such TEM mode resonator.

[0002] The use of TEM mode resonators in filters is known. Such resonators typically include a metal tab which at one end is connected to the signal line of the filter and at the other end is received in a conduit extending through a dielectric core of the resonator. The tab is electrically connected to an electrically conducting coating covering the conduit wall. The coating further partially covers the outer surface of the dielectric forming a resonant chamber. The metal tab is not close to ground and so behaves as an inductor in series with the resonator. The extra inductance is a parasitic element and can affect the resonator performance, particularly the input coupling, resonant frequency and Q.

[0003] For applications where the passband or stopband of the filter is wide compared to the resonant frequency the parasitic effect is difficult to compensate for.

[0004] The dielectric TEM mode resonator according to the invention seeks to overcome the drawbacks of the prior art.

[0005] In a first aspect the present invention provides a dielectric TEM mode resonator comprising

a dielectric core comprising first and second spaced apart faces and a side wall extending therebetween, the first and second faces and side wall together defining an exterior surface;

a conduit extending through the dielectric core from an aperture in the first face to an aperture in the second face, the conduit wall defining an interior surface;

an electrically conducting coating layer, the electrically conducting coating layer extending from the first aperture to at least partially coat the interior surface and at least partially coat the exterior surface, the coating not extending over the exterior surface as far as the second aperture;

an electrically conducting rod at least partially within the conduit; and,

an electrically insulating layer sandwiched between the rod and metal coating on the interior surface such that the rod is not in electrical contact with the electrically conducting coating.

[0006] The electrical design and performance of resonators according to the invention is significantly simpler than known resonators.

[0007] A further advantage of the resonator according to the invention is that it is at least partially temperature compensated as described in greater detail below.

[0008] Preferably the electrically conducting coating layer covers the whole length of the interior surface.

[0009] Alternatively, the electrically conducting coating layer covers the interior surface part way from the first aperture to the second aperture.

[0010] Preferably, the electrically conducting coating layer covers the first face.

[0011] Preferably, the electrically conducting coating layer covers the side wall.

[0012] Preferably, the electrically conducting coating layer does not cover the second face.

[0013] Alternatively, the electrically conducting coating layer partially covers the second face.

[0014] Preferably, the rod extends through the second aperture into the conduit.

[0015] Preferably, the resonator further comprises a displacement means for moving the rod into and out of the conduit.

[0016] In a further aspect of the invention there is provided a bandstop filter comprising

an input port;

an output port;

a signal line extending between input and output ports; and,

at least one resonator as claimed in any one of clams 1 to 9, the rod of the at least one resonator being connected to the signal line.

[0017] Preferably, the bandstop filter further comprises a plurality of resonators as claimed in any one of claims 1 to 9, the rods of each of the resonators being connected to the signal line.

[0018] The present invention will now be described by way of example only and not in any limitative sense with reference to the accompanying drawings in which

Figure 1 shows a known dielectric TEM mode resonator;

Figure 2 shows the equivalent circuit of the resonator of figure 1;

Figure 3 shows a first embodiment of a resonator according to the invention;

Figure 4 shows the equivalent circuit of the resonator of figure 3;

Figure 5 shows a further embodiment of a resonator according to the invention;

Figure 6 shows a further embodiment of a resonator according to the invention;

Figure 7 shows a filter including a plurality of resonators according to the invention; and,

Figure 8 shows a further embodiment of a filter including a plurality of resonators according to the invention.

[0019] Shown in figure 1 is a known dielectric TEM mode resonator 1. The resonator 1 comprises a dielectric core 2. The core 2 comprises first and second spaced apart faces 3,4. Extending between the faces 3,4 is a side wall 5. A conduit 6 extends between a first aperture 7 in the first face 3 and a second aperture 8 in the second face 4. A metal coating 9 partially covers the dielectric core 2. The coating 9 covers the wall of the conduit 6, the first face 3 and the side wall 5 as shown. It does not cover the second face 4.

[0020] Inserted into the conduit 6 is a metal tab 10. The metal tab 10 is in electrical contact with the metal coating 9. When included in a filter the opposite end of the metal tab 10 is connected to the signal line 11 as shown.

[0021] The equivalent circuit for the known resonator of figure 1 is shown in figure 2. As can be seen because the metal tab 10 is not close to ground it acts as an inductor 12 in series with the resonator 1. This complicates design of the circuit including the resonator 1. This is particularly the case when the filter is designed to operate over a wide frequency range with the resonator 1 acting as a narrowband bandstop filter within the frequency range. The properties of the resonator 1 can vary significantly depending upon where in the wide frequency range it operates.

[0022] Shown in figure 3 is a first embodiment of a resonator 20 according to the invention. The resonator 20 comprises a dielectric core 21. In this embodiment the dielectric core 21 is substantially cubic although other shapes of core are possible. The core 21 comprises first 22 and second 23 spaced apart faces. A side wall 24 extends between the faces 22,23. Extending through the core 21 between a first aperture 25 in the first face 22 and a second aperture 26 in the second face 23 is a hollow conduit 27. In this embodiment the conduit 27 is square in cross section. In alternative embodiments the conduit 7 can be other shapes in cross section, for example circular or elliptical

[0023] The side wall 28 of the conduit 27 defines an interior surface 29. The first and second faces 22,23 and side wall 24 together define an exterior surface 30.

[0024] An electrically conducting coating 31, in this case a metal layer, partially coats the dielectric core 21. In this embodiment the coating 31 covers the entire interior surface 29 between the first and second apertures 25,26. It also partially covers the exterior surface 30, covering the first face 22 and side wall 24. The coating 31 does not extend as far as the second aperture 26 and in particular does not cover the second face 23.

[0025] Arranged in the conduit 27 is an electrically conducting rod 32. The rod 32 extends through the second aperture 26 into the conduit 27. Sandwiched between the rod 32 and the wall 28 of the conduit 27 is an insulating layer 33, in this case PTFE, such that the rod 32 is not in direct electrical contact with the electrically conducting coating 31.

[0026] When used in a filter the opposite end of the rod 32 is connected to the signal line 34 of the filter as shown.

[0027] The equivalent circuit for the resonator 20 according to the invention is shown in figure 4. As can be seen the resonator 20 does not present an inductor in series with the resonator 20. This significantly simplifies design and performance of the behaviour of filters including such resonators 20.

[0028] Shown in figure 5 is a further embodiment of a resonator 20 according to the invention. The resonator 20 is similar to that of figure 3 except the electrically conducting coating layer 31 partially covers the second face 23. The electrically conducting layer also only extends part way along the inner surface 29.

[0029] The resonator 20 of figure 5 further comprises a displacement means 35 connected to the rod 32. The displacement means 35 can be controlled to move the rod 32 into and out of the conduit 27 so altering the capacitive coupling between the rod 32 and the remainder of the resonator 20. This alters the resonant frequency of the resonator 20. When the resonator 20 is used as part of a filter one can tune the bandstop region of the filter by moving the rod 32 in the conduit 27. In this embodiment the displacement means 35 comprises a motor for displacing the rod 32. Optionally the motor can be controlled remotely.

[0030] Figure 6 shows a further embodiment of a resonator 20 according to the invention. The second face 23 of the resonator 20 abuts a spacing layer 36. In this embodiment the spacing layer 36 is a circuit board on which the resonator 20 is arranged. Extending through the circuit board 36 is an aperture 37. Arranged over the aperture 37 and attached to the circuit board is a nut 38. A thread 39 extends around the outer face of the rod 32. The rod 32 is threaded through the nut 38, through the aperture 37 and into the conduit 27 as shown. By rotating the rod 32 it can be inserted into or removed from the conduit 27 so changing the resonant frequency of the resonator 20. In this embodiment the nut 38 and thread 39 in combination comprise the displacement means 35.

[0031] An advantage of the resonator 20 of figure 6 is that it is at least partially temperature compensated. The length of the rod 32 varies with temperature, as does the thickness of the spacing layer 36. Expansion of the rod 32 increases the length of rod 32 within the conduit 27. On the other hand, expansion of the spacing layer 36 decreases the length of rod 32 in the conduit 27. If one has the correct length of rod 32 within the conduit 27 then these two effects substantially cancel out so producing a resonator 20 with a temperature independent resonant frequency within a temperature range. When the rod 32 is in other positions partial temperature compensation is achieved.

[0032] Figure 7 shows a filter 40 employing a plurality of resonators 20 according to the invention. The filter 40 comprises an input port 41 and an output port 42 and a

signal line 43 extending therebetween. Connected in series in the signal line is a plurality of inductors 44. The inductors 44 are connected together at nodes 45. Further connected to each node 45 is the rod 32 of a resonator 20 according to the invention. Further connected between each node 45 and earth is a capacitor 46. The end inductors 44 in the series are connected to the input 41 and output 42 ports at further nodes 45. Connected between each of these further nodes 45 and earth are capacitors 46.

[0033] The filter 40 acts as a passband filter over a wide frequency range above and below its stopband. The resonators 20 provide relatively narrow regions over which the filter 40 acts as a bandstop filter. By moving the rods 32 within the conduits 27 these bandstop regions can be moved up and down within the bandpass range of the filter 40. Because the equivalent circuits of the resonators 20 according to the invention do not provide an inductor in series with the resonator 20 the properties of the resonators 20 do not substantially change as the bandstop region of the resonator 20 changes. This significantly simplifies the design and performance of the filter 40.

[0034] Figure 8 shows a further embodiment of a filter 40 according to the invention. This embodiment is similar to that of figure 7 with the inductors 44 replaced by transmission lines 47. In this embodiment there are no capacitors 46 to earth.

[0035] In a further alternative embodiment of the invention the rod 32 is inserted into the conduit 27 via the first aperture 25.

Claims

1. A dielectric TEM mode resonator comprising
a dielectric core comprising first and second spaced apart faces and a side wall extending therebetween, the first and second faces and side wall together defining an exterior surface;
a conduit extending through the dielectric core from an aperture in the first face to an aperture in the second face, the conduit wall defining an interior surface;
an electrically conducting coating layer, the electrically conducting coating layer extending from the first aperture to at least partially coat the interior surface and at least partially coat the exterior surface, the coating not extending over the exterior surface as far as the second aperture;
an electrically conducting rod at least partially within the conduit; and,
an electrically insulating layer sandwiched between the rod and metal coating on the interior surface such that the rod is not in electrical contact with the electrically conducting coating.

2. A resonator as claimed in claim 1, wherein the electrically conducting coating layer covers the whole length of the interior surface.

3. A resonator as claimed in claim 1, wherein the electrically conducting coating layer covers the interior surface part way from the first aperture to the second aperture.

4. A resonator as claimed in any one of claims 1 to 3, wherein the electrically conducting coating layer covers the first face.

5. A resonator as claimed in claim 4, wherein the electrically conducting layer covers the side wall.

6. A resonator as claimed in claim 5, wherein the coating layer does not cover the second face.

7. A resonator as claimed in claim 5, wherein the coating layer partially covers the second face.

8. A resonator as claimed in any one of claims 1 to 7, wherein the rod extend through the second aperture into the conduit.

9. A resonator as claimed in any one of claims 1 to 8, further comprising a displacement means for moving the rod into and out of the conduit.

10. A bandstop filter comprising
an input port;
an output port;
a signal line extending between the input and output ports; and,
at least one resonator as claimed in any one of claims 1 to 9, the rod of the at least one resonator being connected to the signal line

11. A bandstop filter as claimed in claim 10, comprising a plurality of resonators as claimed in any one of claims 1 to 9, the rods of each of the resonators being connected to the signal line.

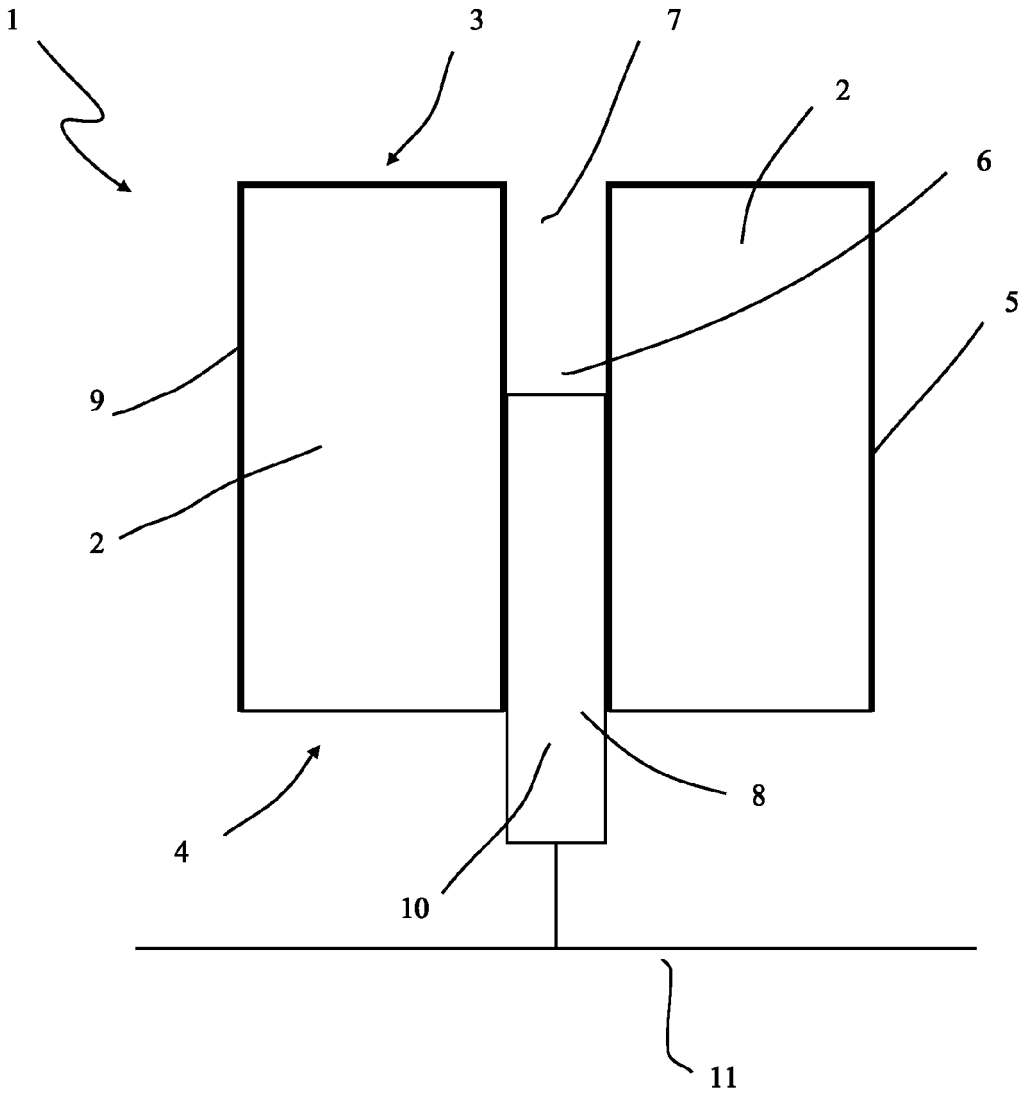

Figure 1

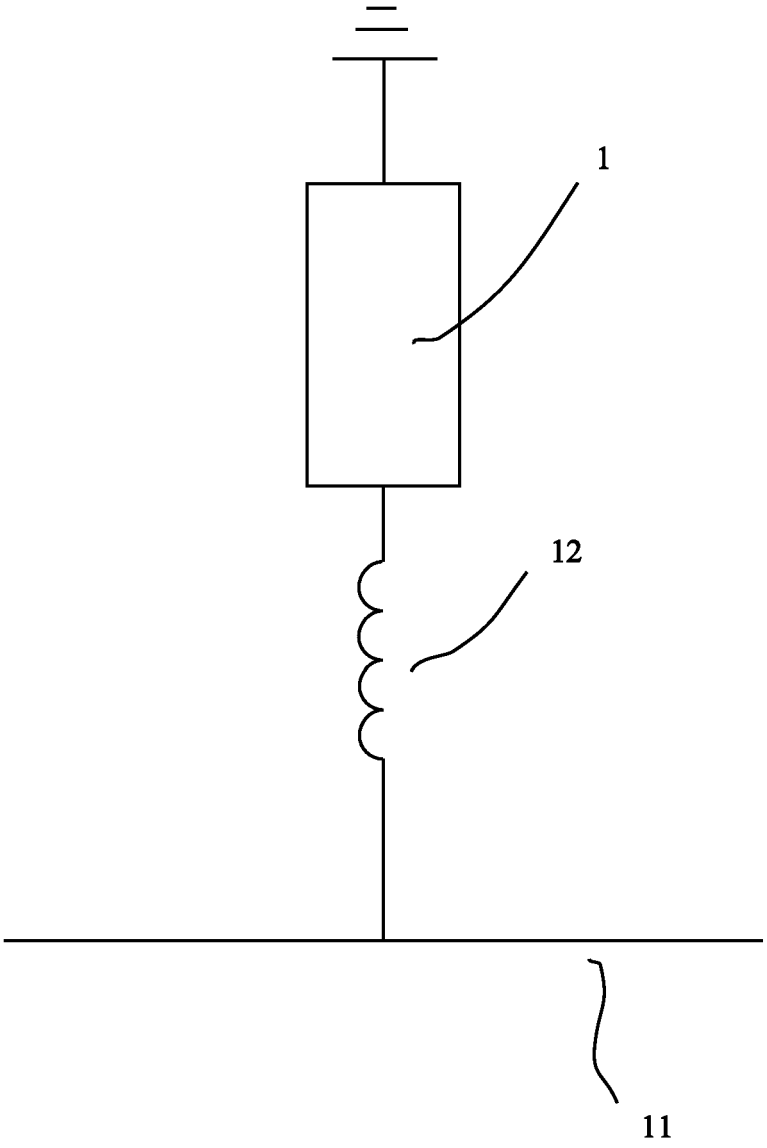

Figure 2

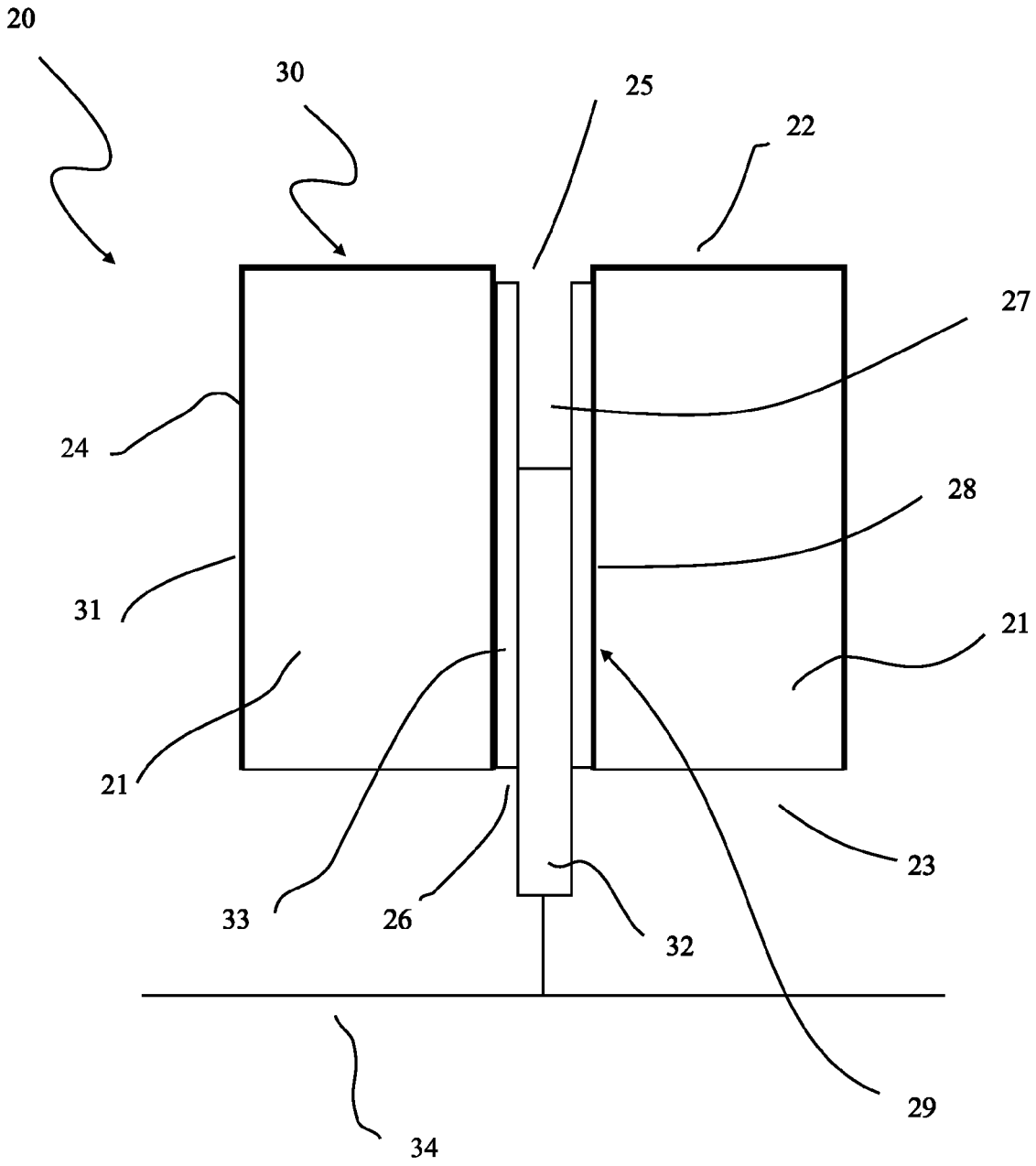

Figure 3

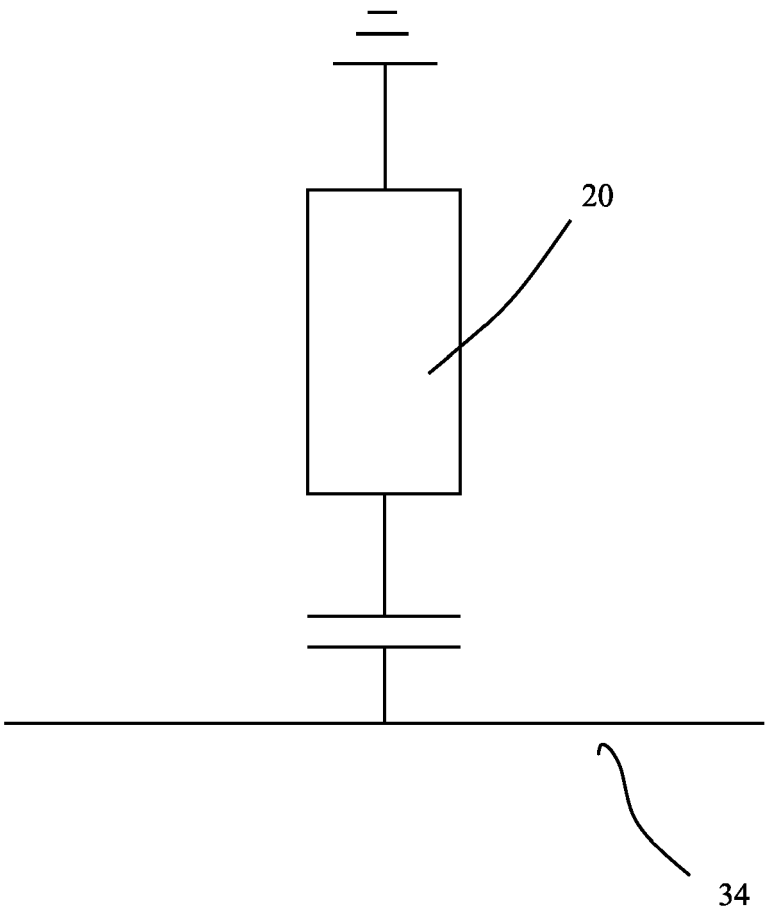

Figure 4

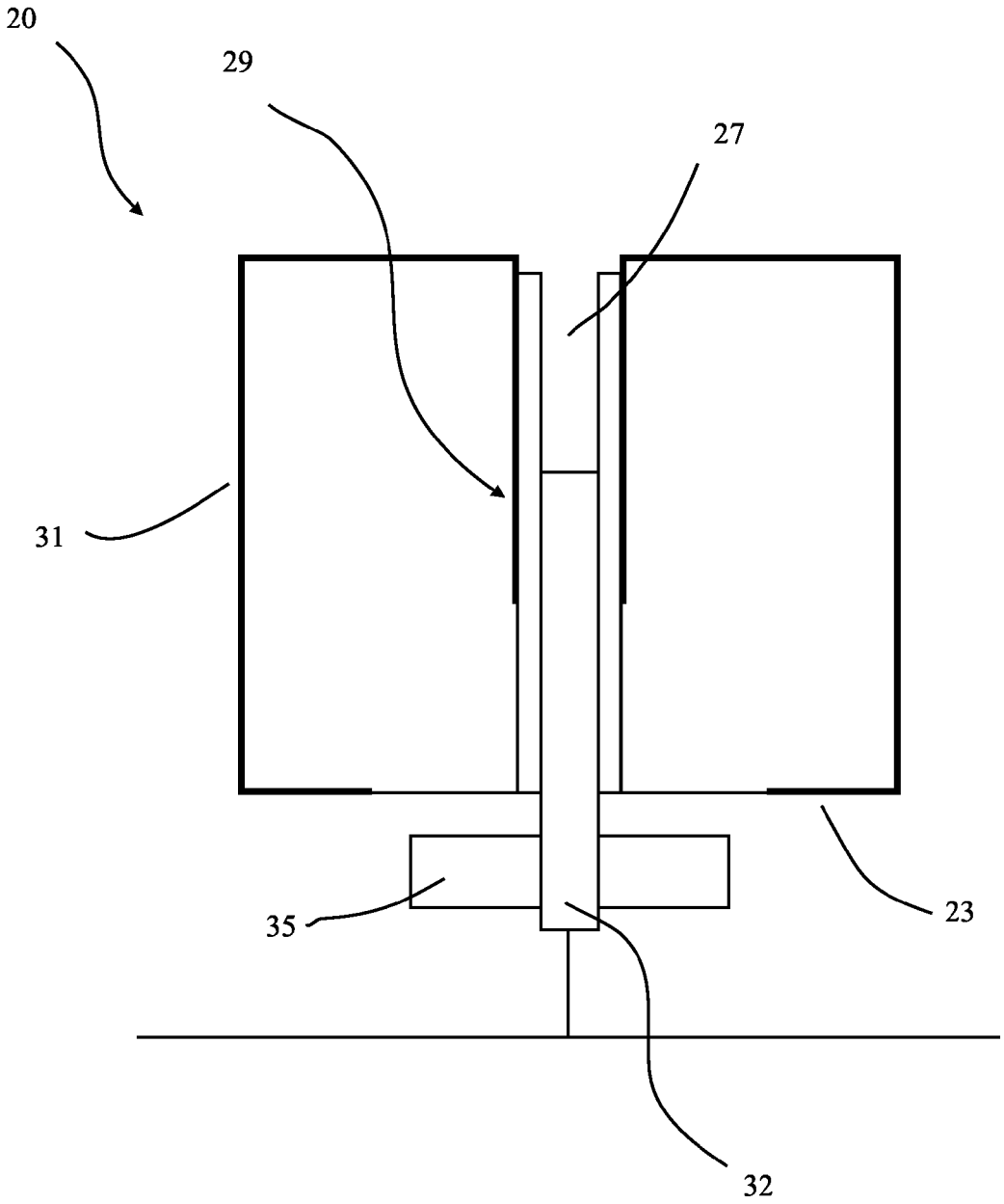

Figure 5

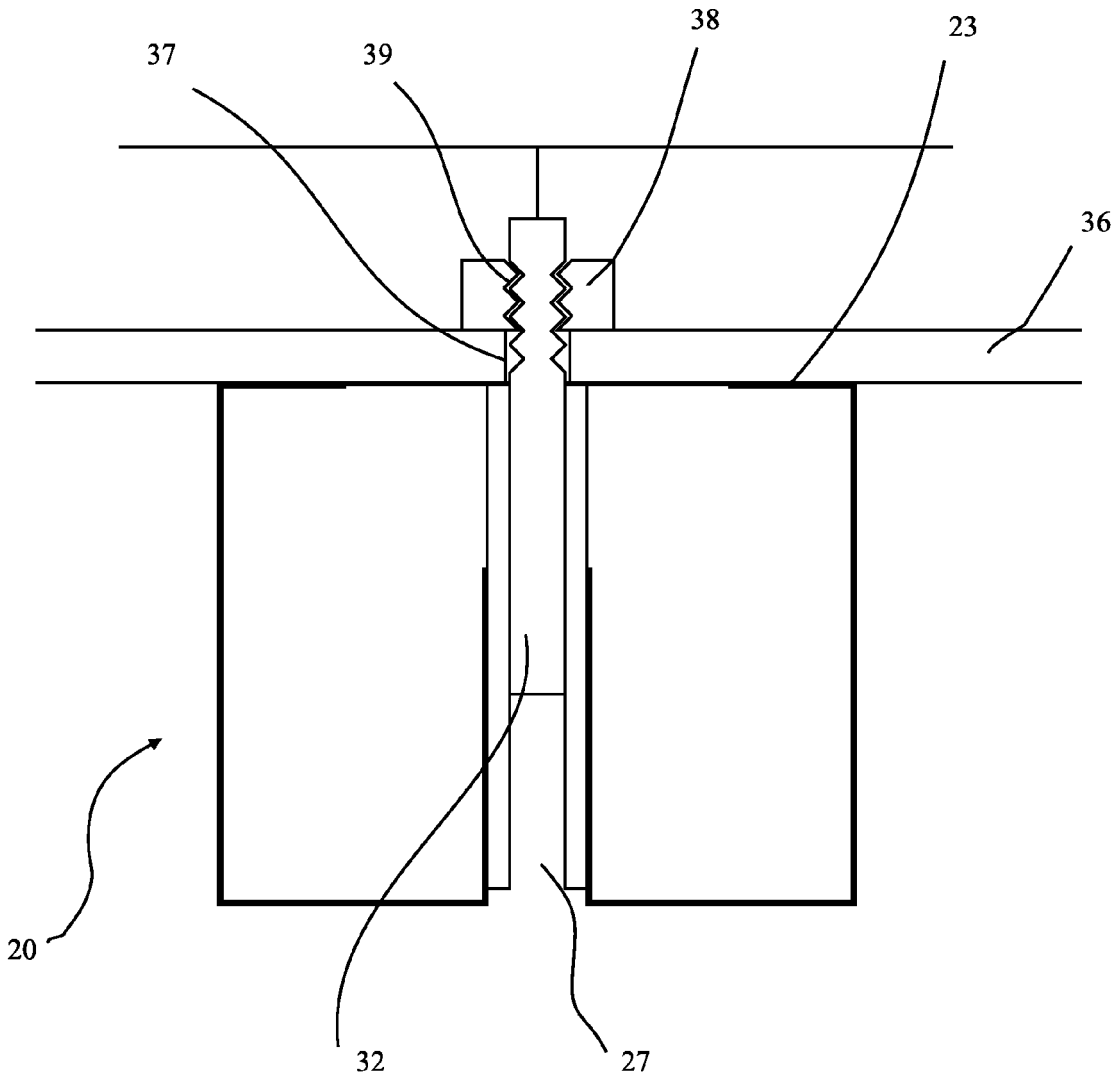

Figure 6

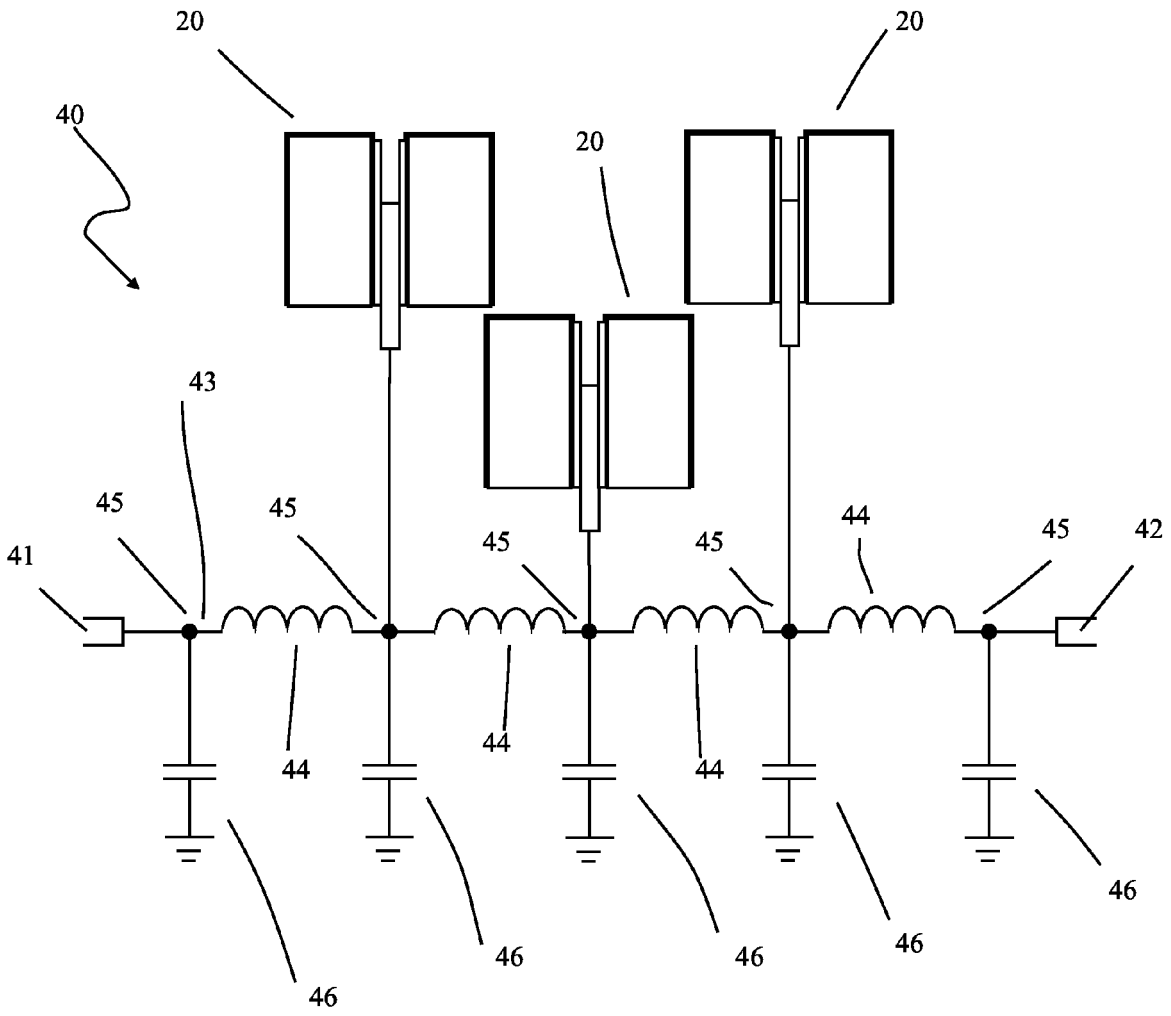

Figure 7

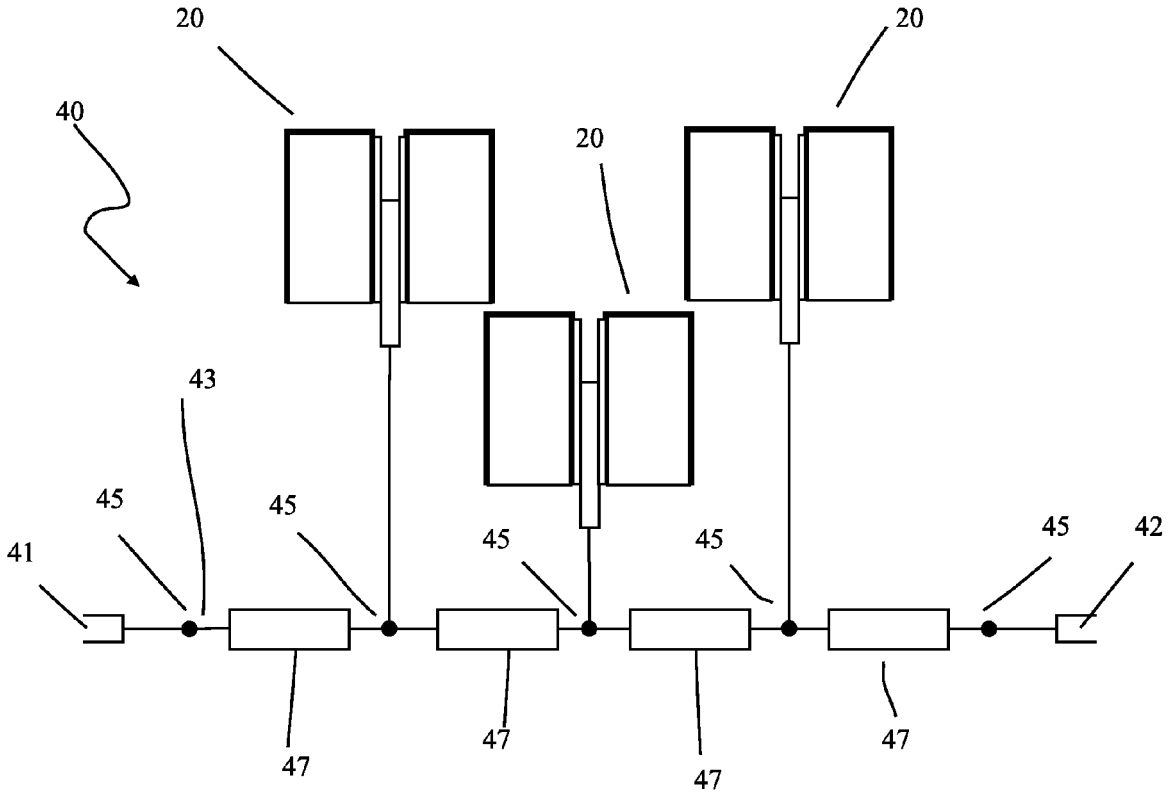

Figure 8

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 8947

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	US 5 216 394 A (KONISHI YOSHIHIRO [JP] ET AL) 1 June 1993 (1993-06-01) * column 1, line 19 - line 36 * * figure 1A * * abstract * -----	1,2,4-6, 8-11 3,7	INV. H01P7/04 H01P7/10
X Y	EP 0 785 592 A1 (LK PRODUCTS OY [FI]) 23 July 1997 (1997-07-23) * column 2, line 3 - line 22 * * figure 1 * * abstract * -----	1,2,4-6, 8-11 3,7	
Y	JP S61 245602 A (ALPS ELECTRIC CO LTD) 31 October 1986 (1986-10-31) * figures 1-3 * * abstract * -----	3,7	
Y	EP 0 399 049 A1 (MATSUSHITA ELECTRIC IND CO LTD [JP]) 28 November 1990 (1990-11-28) * page 1, line 22 - page 3, line 20 * * figures 14(A), 14(B) * * abstract * -----	3,7	TECHNICAL FIELDS SEARCHED (IPC) H01P
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	25 July 2013	von Walter, Sven-Uwe

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 16 8947

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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