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(54) **A bandwidth tunable filter and a method for constructing and tuning such a filter**

(57) A filter is disclosed that comprises a plurality of resonator members including an input resonator member and an output resonator member each of the plurality of resonator members being mounted on a surface within a conductive housing. The filter has an input feed line configured to transmit a signal to the input resonator member such that the signal excites the input resonator member, the plurality of resonator members being arranged such that the signal is transferred between the plurality of resonator members to an output resonator member. There is an output feed line for receiving the signal from the output resonator member and for outputting the signal. A conductive tuning member protrudes between at least one of the feed lines and an inner surface of the conductive housing such that the conductive tuning member affects a capacitance of the at least one of the feed lines allowing it to be bandwidth tuned.

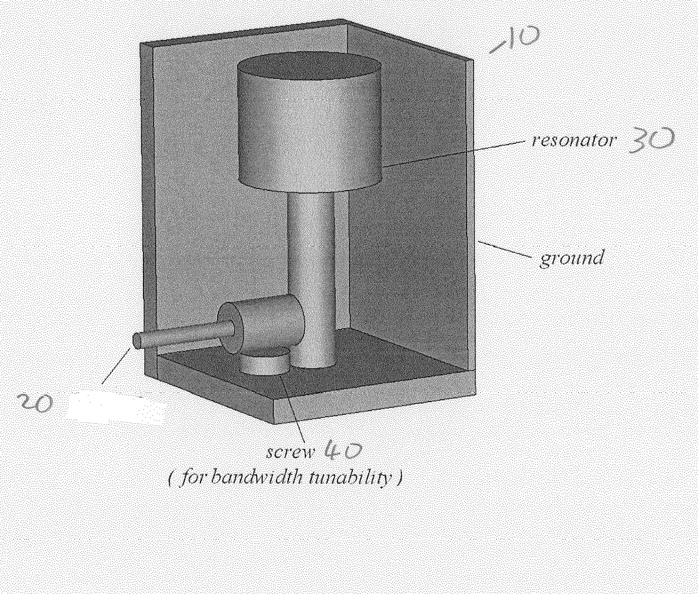

Figure 4

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Description

FIELD OF THE INVENTION

[0001] The invention relates to filters, methods for tuning and constructing such filter.

BACKGROUND

[0002] Filters are widely used in data transmission and in particular, telecommunications, for example in base stations, radar systems, amplifier linearization systems, point-to-point radio, and RF signal cancellation systems. Although a specific filter is chosen or designed dependent on the particular application, there are certain desirable characteristics that are common to all filter realisations. For example, the amount of insertion loss in the pass-band of the filter should be as low as possible, while the attenuation in the stop-band should be as high as possible. Further, in some applications the frequency separation between the pass-band and stop-band (guard band) needs to be very small, which requires filters of high order to be deployed in order to achieve this requirement. However, the requirement for a high order filter is always followed by an increase in the cost (due to the greater number of components that such a filter requires) and space. Furthermore, even though increasing the order of the filter increases the attenuation in the stop-band, it inevitably increases the losses in the pass-band.

[0003] One of the important requirements often imposed on filters is that of tunability, i.e. the ability of a filter to vary its frequency of operation and percentage bandwidth. This requirement if often considered as "the holy grail" in filter design, especially if the variation of the operating frequency and the bandwidth of the filter do not significantly deteriorate other important filter parameters (such as pass-band loss and rejection).

[0004] Some tunability of cavity combline filters has been achieved using tuning screws. Figure 1a shows a third order cavity combline filter according to the prior art, Figure 1b showing an equivalent circuit for such a filter. The filter is designed to operate at a particular frequency and bandwidth. However, in order to fine tune the filter and adjust for manufacturing tolerances, tuning and coupling screws are provided. The tuning screws vary the distance between the housing and the free end of the resonant post and change the frequency of operation of the filter. The coupling screws are located in the gaps between the cavities and alter the coupling between the cavities and thereby the bandwidth of operation.

[0005] These screws provide the ability to fine tune a filter to compensate for manufacturing tolerances, however, where a more dramatic change in frequency or bandwidth is required then, this may not be possible with these existing mechanisms. It would be desirable to have a filter whose bandwidth could be tuned.

SUMMARY

[0006] A first aspect of the present invention provides a filter comprising: a plurality of resonator members comprising an input resonator member and an output resonator member each of said plurality of resonator members being mounted on a surface within a conductive housing; an input feed line configured to transmit a signal to said input resonator member such that said signal excites said input resonator member, said plurality of resonator members being arranged such that said signal is transferred between said plurality of resonator members to an output resonator member; an output feed line for receiving said signal from said output resonator member and outputting said signal; and a conductive tuning member protruding between at least one of said feed lines and an inner surface of said conductive housing such that said conductive tuning member affects a capacitance of said at least one of said feed lines.

[0007] Filters can be designed to operate at certain frequencies and with certain bandwidths and quality factors. These properties may be changed at the design stage by changing not only the size and shape of the resonant member and/ or housing but also by changing the physical feed position of the input and output feed line. However, once these parameters are set, changing these properties and tuning the filter is more difficult. The present invention recognises that the loaded quality factor of a filter, which is its quality factor when connected to other devices and is dependent on the frequency of operation, is affected by the position and impedance of the feed lines which are generally set at the design stage. The value of the loaded Q affects the bandwidth of the filter, the higher the loaded Q the narrower the bandwidth.

[0008] Although in traditional filters, the coupling coefficients between internal resonator assemblies or resonator members mounted within resonant cavities can be adjusted using coupling screws, it is not so clear how the loaded Q factor can be tuned, since this parameter is usually set by the physical feed position of the feed line. In other words, once the feed is attached to the housing of the filter, the loaded Q factor is also set, and the filter designer has virtually no freedom to change it, unless the physical position of the feed is changed.

[0009] Thus, the lack of a loaded Q factor tuning mechanism is a missing link towards the achievement of a frequency agile and bandwidth tunable filter.

[0010] Looking at an input resonator assembly or resonator member mounted in a resonant cavity of a filter such as that shown in Fig. 2, the input reflection coefficient of the circuit of this figure at resonance can be written as

$$S_{11} = \frac{Y_0 G - \omega_0^2 C_k^2}{Y_0 G + \omega_0^2 C_k^2} \quad (1)$$

where $Y_0 = \frac{1}{Z_0}$ is the characteristic admittance of the input feed line and ω_0 is the resonant frequency. G represents the equivalent conductance related to the unloaded Q factor of the resonator assembly. The unloaded Q factor can be defined in the most general way as energy stored divided by energy dissipated times frequency. In other words it is a measure of stored vs lost energy per unit time. It is a characteristic of a resonator assembly and should be as high as possible and should not therefore be changed.

[0011] The loaded Q factor of the resonator assembly is given by

$$Q_e = \frac{\omega}{4} t_d \,(2)$$

[0012] Where t_d represents the time delay given by

$$t_d = \left. \frac{\partial S_{11}}{\partial \omega} \right|_{\omega=\omega_0} \quad \frac{4\omega_0 Y_0 G C_k^2}{(Y_0 G + \omega_0^2 C_k^2)^2} \,(3)$$

[0013] Which after substitution in (2) yields

$$Q_e = \frac{\omega_0^2 Y_0 G C_k^2}{(Y_0 G + \omega_0^2 C_k^2)^2} \quad (4)$$

[0014] From this equation one can see that the loaded Q varies with characteristic admittance Y_0, of the interconnecting line which cannot be changed, since it is set by external factors (connection to other equipment and standards) and with G which is the equivalent conductance of the resonator assembly. G is frequency dependent and for the particular frequency of operation cannot be altered as the unloaded Q factor depends on it and this needs to be kept as high as possible and should not be changed in filter design. This leaves the capacitance C_k, and changes in this will change the loaded Q factor. Thus, this can be used to vary the loaded Q and in this way tune the bandwidth. Thus, the inventor realised that the loaded Q could be changed post manufacture by changing the capacitance of the feed line by the insertion of a conductive tuning member protruding between the feed line and an inner surface of the conductive housing. Such a conductive tuning member affects the capacitance and therefore the impedance of the feed line which in turn affects the loaded Quality factor and the bandwidth of the filter. In this simple yet effective way the bandwidth of the filter can be changed after manufacture.

[0015] In some embodiments the filter comprises two conductive tuning members one protruding between said output feed line and an inner surface of said conductive housing thereby affecting a capacitance of said output feed line and one protruding between said input feed line and an inner surface of said conductive housing thereby affecting a capacitance of said input feed line.

[0016] Although the filter may be tuned at only one of the input or output feed lines, in general it is advantageous if the feed lines are balanced and thus, tuning of both input and output feed lines in conjunction with other can lead to both a tunable and efficient filter.

[0017] In some embodiments, said conductive tuning member is a movable tuning member configured to move such that a distance that said protruding member extends from said inner surface of said conductive housing can be varied, said capacitance of said input or output feed line affected by said protruding member varying with said distance and thereby changing a bandwidth of said filter.

[0018] Although the tuning member can be configured in a number of ways, it may be advantageous if it is a movable member such that a distance that it extends from the inner surface can be changed, thereby changing the capacitance, impedance and bandwidth.

[0019] In some embodiments, said tuning member comprises a screw extending from said inner surface of said conductive housing towards said input or output feed line.

[0020] One simple yet effective way or providing a movable conductive tuning member is to provide it as a screw, such that the distance can be altered by simply rotating the screw which will then retain its new position.

[0021] Although the filter may take a number of forms in some embodiments said filter is at least one of a radio frequency and a combline filter. The present technique is particularly effective at tuning such filters.

[0022] In some embodiments, said input and output feed lines run substantially perpendicular to a longitudinal access of said resonant members from an inner surface of said housing to abut against said input and output resonant members respectively, said conductive tuning member extending from a same inner surface of said housing or from an adjacent inner surface as said feed line extends from and wherein a plane that passes through said longitudinal access of said resonant member and said feed line passes through said tuning member.

[0023] The resonant members and feed lines may be arranged in a number of different ways, a suitable location of the tuning member will depend on the particular configuration. Where, for example, the feed lines abut the resonant member the tuning member may extend from the same inner surface or an adjacent inner surface as the surface that the feed line extends from, thereby providing an effective way of changing the capacitance of the feed line.

[0024] In some embodiments, a first portion of said feed lines extends substantially perpendicular to a longitudinal access of said resonant members towards said respective resonant members from an inner wall of said housing running parallel to said longitudinal access and a second portion located towards but at a distance from said respective resonant members extends substantially parallel to said longitudinal access, said conductive tuning member extending from one of said inner walls of said housing on a same side of said resonant member as said feed line

[0025] Where the feed lines do not abut the resonant member but extend towards it from a side wall, then the tuning member may be located close to the feed line either extending from the same inner wall or from an adjacent one in the same plane as the feed line. Thus, if the feed line is extending from the side wall the tuning member may extend from the same side wall or one of the upper or lower walls.

[0026] In other embodiments, said feed lines run substantially parallel to a longitudinal access of said resonant members, said conductive tuning member extending from a surface of an inner wall of said housing, said feed line lying between said surface of said inner wall from which said conductive tuning member extends and said resonant member. In some embodiments said plurality of resonant members are each mounted within a respective resonant chamber, said resonant chambers being formed by walls of said housing and partition walls within said housing, at least some of said partition walls not extending between opposing walls of said housing such that said resonant chambers are not completely isolated from each other by said partition walls.

[0027] The filter is generally formed to have resonant chambers with the resonant members each located within a chamber. The chambers are connected via gaps in the separating walls allowing the signal to be coupled between chambers.

[0028] In some embodiments said housing contains a granular dielectric material such that said plurality of resonant members are surrounded by said granular dielectric material and in some cases said housing is at least substantially filled with said plurality of resonant members and said granular dielectric material.

[0029] One way of changing the frequency of operation of a filter and reducing its size is to surround the resonant member with a dielectric material rather than air. This dielectric loading of the cavity increases the dielectric constant of the overall cavity as compared to the empty cavity, effectively reducing the value of the guided wavelength inside the cavity. The overall size reduction of the filter is directly proportional to the value of the dielectric constant of the powder that is used to load the cavities of the particular filter. It is important to realise that the dielectric powder loading of a filter does not only reduce the size of the filter, but that the coupling coefficients between the internal resonator assemblies are not dependent on the value of dielectric constant of the powder. More specifically, for the given values of coupling wall openings, the coupling coefficients remain the same, regardless of whether the cavity is empty or filled with a dielectric material of an arbitrary value, provided of course that the dielectric loss is not so extreme that that the electromagnetic field in the cavity is absorbed by it.

[0030] Thus, the dielectric loading of filters does not change the inter-resonator couplings. However, dielectric loading does influence the loaded Q factor and ultimately the bandwidth of the filter. In effect dielectric loading of empty cavities of, for example, an RF filter results in the reduction of the operating frequency of the filter in proportion to $\sqrt{\varepsilon_r}$. Thus, frequency tunability can be obtained by controlled dielectric loading; however, as this also affects bandwidth then the tuning of the bandwidth becomes important. Embodiments of the present invention are particularly applicable to filters filled with dielectric powders where the frequency has been significantly changed and a change in bandwidth is required to allow the filter to operate within its required specifications.

[0031] The present technique allows filters that have granular dielectric material within them, and have a corresponding adjustment or tuning of the frequency, to have their bandwidth altered such that a suitable filter with the required specifications can be generated. Embodiments of the present technique therefore provide a filter with frequency tunability using a dielectric power and bandwidth and loaded Quality tunability using a conductive tuning member.

[0032] Preferably, the dielectric material has at least one of a relative dielectric constant in the range 2 to 10, more preferably in the range between 3 to 5 and a loss tangent in the range 4 $x10^{-4}$ to 4 $x10^{-5}$.

[0033] In some cases the dielectric material is one of a manufactured dielectric powder while in others it is formed of granular fused quartz such as sand. The latter is a cheap, stable and yet effective dielectric powder to use.

[0034] A second aspect of the present invention provides a method of adjusting a bandwidth of a bandpass filter, said bandpass filter comprising: a plurality of resonator members comprising an input resonator member and an output resonator member each of said plurality of resonator members being mounted on a surface within a conductive housing; an input feed line configured to transmit a signal to said input resonator member such that said signal excites said input resonator member, said plurality of resonator members being arranged such that said signal is transferred between said plurality of resonator members to an output resonator member; an output feed line for receiving said signal from said output resonator member and outputting said signal; and a conductive tuning member protruding between at least one of said feed lines and an inner surface of said conductive housing; said method comprising moving said conductive tuning member such that a distance that it protrudes from said inner surface of said conductive housing towards at least one feed line changes, a bandwidth of said filter changing in response to said change.

[0035] A third aspect of the present invention provides a method of constructing a filter with a desired bandwidth comprising: arranging a plurality of resonator members comprising an input resonator member and an output resonator member on a surface within a conductive housing in such a way that a signal exciting said input resonator is transferred between said plurality of resonator members to an output resonator member; introducing an input feed line into said housing to transmit a signal to said input resonator member such that said signal excites said input resonator member; introducing an output feed line into said housing to receive a signal from said output resonator member; introducing a conductive tuning member to protrude between at least one of said feed lines and an inner surface of said conductive housing, said protruding member affecting a capacitance of said at least one feed line; and adjusting a distance that said conductive tuning member protrudes from said inner surface of said housing towards said at least one feed line to attain a desired bandwidth for said filter.

[0036] In some embodiments said method comprises a further step performed prior to adjusting said distance that said conductive tuning member protrudes, of filling said housing with a granular dielectric material.

[0037] Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0038] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1a and 1b illustrate a third order combline filter and equivalent circuit according to the prior art;
Figure 2 illustrates an input/output resonator assembly and equivalent circuit;
Figure 3 illustrates a schematic view of an input/output resonator assembly according to an embodiment of the present invention;
Figure 4 illustrates a perspective view of the resonator assembly of Figure 3;
Figure 5 shows variations in the loaded Q value with screw intrusion depth for a resonator such as that of figure 4 within a 5th order bandpass Chebyshev filter;
Figure 6 shows insertion losses for different screw intrusion depths;
Figure 7 shows the return loss for different screw intrusion depths;
Figures 8 and 9 illustrate two different input/output resonator assemblies according to an embodiment of the present invention;
Figure 10 illustrates a combline filter according to an embodiment of the present invention; and
Figure 11 illustrates a flow diagram showing steps in a method of constructing and tuning a filter according to an embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

Overview

[0040] Before discussing the embodiments in any more detail, first an overview will be provided.

[0041] The present technique provides a filter particularly for use in radio frequency applications that comprises resonator assemblies or resonator members in resonant chambers coupled together. A signal is input via a feed line to an input resonator member and then travels between the resonator members until it is output via an output resonator member to an output feed line. The bandwidth of the filter may be tuned by varying a loaded quality factor Q of the filter using a conductive member arranged so as to change the capacitance of the feed line(s) and thereby the loaded quality factor and bandwidth.

[0042] In some cases the resonant chambers of the filter maybe loaded with a dielectric powder, this changes the frequency of resonance of the filter and allows filters to be made smaller and indeed to be frequency tuned using the powder. However, the powder affects the bandwidth of the filter and thus, the change in bandwidth needs to be compensated for if a filter with the required specifications that operates at the required frequency is to be achieved. The present technique provides an effective way of changing the loaded quality factor and bandwidth of the filter as required allowing a tunable filter filled with dielectric powder to be produced.

[0043] In this regard, although in traditional filters the coupling coefficients between internal resonator assemblies can be adjusted using coupling screws, it is not so clear how the loaded Q factor can be tuned, since this parameter is usually set by the physical feed position of the input feed line, in the case of an RF filter the RF probe. In other words, once the feed is attached to the housing of the filter, the loaded Q factor is also set, and the filter designer has virtually no freedom to change it, unless the physical position of the feed is changed.

[0044] Thus, the lack of a loaded Q factor tuning mechanism was a missing link towards the achievement of the frequency agile and bandwidth tunable filter. Where frequency tunability is obtained by controlled dielectric loading, this affects bandwidth and the tuning of the bandwidth becomes particularly important. Thus, embodiments of the present invention are particularly applicable to filters filled with dielectric powders where the frequency has been significantly changed by the powder and a change in bandwidth is required to allow the filter to operate within its required specifications.

[0045] A consideration of Fig. 1a provides the reasons for this. This figure shows the equivalent circuit of a third order combline filter, where the combline resonator assemblies are represented by parallel LC circuits, whereas the couplings (wall openings) between the resonator assemblies are represented by admittance inverters. The equivalent circuit of an admittance inverter, together with two adjacent resonator assemblies is given in Fig. 1b. At resonance,

$$\omega_0 L_0 = \frac{1}{\omega_0 C_0} \quad (5)$$

[0046] Where

$$\omega_0 L_0 = jZ_0 \tan(\Theta_0) \quad (6)$$

here Z_0 and Θ_0 are the characteristic impedance and the length of the combline resonator assembly and ω_0 is the resonant frequency of the resonator assembly. The coupling coefficient between the resonator assemblies is defined as

$$M^0{}_{k,k+1} = \frac{C_k}{C_0} (3) \quad \forall k > 0 \cap k < n \quad (7)$$

[0047] At this point, let us assume that (5) - (7) refer to the case of the empty cavity, i.e. when there is no dielectric powder present. Upon dielectric powder loading, (5) - (7) can be rewritten to read

$$\omega_d L_d = \frac{1}{\omega_d C_d} \quad (8)$$

$$\omega_d L_d = jZ_d \tan(\Theta_d) \quad (9)$$

$$M^{d}_{k,k+1} = \frac{C_{kd}}{C_d} \quad (6) \quad \forall k > 0 \cap k < n \quad (10)$$

[0048] In (8) - (10), Z_d and Θ_d are the characteristic impedance and the length of the dielectric filled combline resonator assembly and ω_d is the resonant frequency of the dielectric filled resonator assembly. By imposing that the reactance of the air filled resonator assembly at frequency ω_0 remains unchanged at frequency ω_d , the following condition is obtained for the capacitance, C_d

$$C_d = C_0 \frac{\omega_0}{\omega_d} \quad (11)$$

[0049] And in a similar fashion, the expression for C_{kd} is obtained

$$C_{kd} = C_k \frac{\omega_0}{\omega_d} \quad (12)$$

[0050] Now, the expression for the internal coupling coefficient of dielectric filled resonator assemblies is obtained

$$M^{d}_{k,k+1} = \frac{C_{kd}}{C_d} \quad \frac{C_k}{C_0} = (13)$$

i.e. the coupling coefficient has remained the same as it was for the case of empty resonator assemblies. As mentioned earlier, this condition will hold as long as the losses of the dielectric are not prohibitively high, since in that case energy absorption by the dielectric powder will significantly degrade the couplings between the resonator assemblies. However, as stated earlier, high loss dielectric materials are not of use in such filter design, so the statement above applies to a great range of dielectric materials.

[0051] However, as explained earlier the effect of dielectric loading on the loaded quality factor of a filter is somewhat greater. Figure 2 shows an input/output resonator assembly and its equivalent circuit, the value of the loaded Q factor for such a resonator assembly being given by equation (4).

$$Q_e = \frac{\omega_0^2 Y_0 G C_k^2}{(Y_0 G + \omega_0^2 C_k^2)^2} \quad (4)$$

[0052] From this equation one can see that loaded Q varies with characteristic admittance Y_0 , of the interconnecting line which cannot be changed, since it is set by external factors (connection to other equipment and standards) and with G which is the equivalent conductance, G of the resonator assembly. G changes significantly by the adding of the dielectric, however, further adjustment of it should be avoided as it affects the unloaded quality factor which needs to be kept as high as possible.

[0053] This leaves the capacitance C_k, and changes in this will change the loaded Q factor. Thus, this can be used to vary the loaded Q and in this way tune the bandwidth and allow a filter to be frequency tuned by being at least partially filled with dielectric powder while compensating for the undesirable and related changes in loaded Q and bandwidth by adjusting the capacitance of the feed line using a suitably located conductive tuning member.

[0054] Figures 3, 8, and 9 all show possible embodiments of input or output resonant assemblies having different structures.

[0055] Figure 3 shows schematically an example embodiment of an input or output resonator chamber 10 where the tuning member 30 is a screw mounted on the same surface as the resonator member or post 30 shown simply as a block, close to the feed line 20. In order to show how the loaded Q factor varied in response to the tuning member, the structure of Fig. 3 was designed and simulated for different values of intrusion *z* of the tuning member. The resonator assembly of this embodiment, has overall dimensions of 18 x 18 x 25 mm and the cavity is filled with a material of a dielectric constant of 3.8, with a loss tangent of $tan(\delta)=5x10^{-5}$.

[0056] Fig. 4 presents the perspective view of the resonator assembly of Figure 3 shown in more detail. The position of the input feed was initially set at a height of 3.74 mm and this arrangement yielded a loaded Q of about 54 when the tuning member was not present. The bandwidth tunability screw with a diameter of 4 mm was then added, as illustrated in Fig. 4, and its intrusion was varied from 0 to 1.5 mm.

[0057] Fig. 5 presents loaded Q factors for different values of the screw intrusion. The intrusions of the screw in this figure are 0 mm, 0.9 mm and 1.5mm. As can be seen the loaded Q increases with increasing intrusion height, and stands at 95 for a screw intrusion of 1.5mm. The intrusion of the screw also generates a small frequency shift, but this can be easily compensated for using a frequency tuning screw. As a rule of thumb, the higher the loaded Q the smaller the percentage bandwidth of the filter.

[0058] Figure 6 shows the insertion loses of a 5^{th} order bandpass Chebyshev filter which was initially designed for no screw intrusion and for operation in the frequency range 699-716 MHz, with a minimum return loss of 16 dB. Figure 7 shows the return loss of the same filter.

[0059] A bandwidth tunability screw was inserted and for different intrusions, i.e. 0.9 mm and 1.5 mm, the filter was retuned using coupling and tuning screws only, without changes to the dimensions of the resonators and the wall openings.

[0060] As can be seen, the return loss of 16 dB is maintained for all three filters, while the percentage bandwidth is varied from 2.3 % to 1.1 % (corresponding to absolute bandwidths between 16.3 MHz and 8 MHz respectively) for screw intrusions between 0 mm and 1.5 mm.

[0061] Figures 8 and 9 show different structural alternatives of an input or output resonator chamber for use in a filter according to an embodiment of the present invention.

[0062] Figure 8 shows a resonator chamber 10 where the feed line 20 does not abut the resonator member 30 but extends towards it from a side wall. The tuning screw 40 is located on the same side wall as the feed line 20 and can be extended by different amounts into the chamber 10 to change the capacitance of the feed line 20 and thereby the loaded quality factor and the bandwidth. Figure 9 shows an alternative embodiment where the feed line 20 extends from the upper to lower surface of the housing adjacent to the resonator member 30 and the tuning member 40 extends into the housing by a varying amount between a side wall and the feed line 20.

[0063] Figure 10 shows the resonant chambers of Figure 3 arranged as the input and output chambers in a combline filter 5 according to an embodiment of the present invention. As can be seen in this case both the input 20 and output 22 feed lines having tuning screws 40 associated with them, such that their impedance can be changed and thereby the loaded Q factor and bandwidth of the filter 5. In this embodiment there are also frequency tuning screws 50 for varying the frequency of the filter. These may not be present in some embodiments, the frequency being tuned by filling the resonant chambers with suitable dielectric granular material.

[0064] Although in this embodiment the resonant chambers are shown as arranged in a row in a combline filter other arrangements of the resonator chambers to form different filters could be envisaged and provided they had at least one tuning member for changing the capacitance of at least one of the feed lines and therefore the loaded quality factor and bandwidth of the filter, they would be within the scope of the claimed invention.

[0065] Figure 11 shows a flow diagram illustrating steps in a method of constructing and tuning a filter according to an embodiment of the present invention. A plurality of resonator members are arranged in resonant chambers within a conductive housing to form a filter. Input and output feed lines are introduced into the housing for inputting and outputting the signal to be filtered. The housing is filled with a granular dielectric material which changes its frequency of operation. A conductive tuning member that protrudes into the housing close to the feed lines and changes their capacitance is then adjusted so that the bandwidth of the filter is adjusted to the desired level.

[0066] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machineexecutable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

[0067] The functions of the various elements shown in the Figures, including any functional blocks labelled as "processors" or "logic", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" or "logic" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage.

[0068] Other hardware, conventional and/ or custom, may also be included. Similarly, any switches shown in the Figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0069] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0070] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. A filter comprising:

   a plurality of resonator members comprising an input resonator member and an output resonator member each of said plurality of resonator members being mounted on a surface within a conductive housing;
   an input feed line configured to transmit a signal to said input resonator member such that said signal excites said input resonator member, said plurality of resonator members being arranged such that said signal is transferred between said plurality of resonator members to an output resonator member;
   an output feed line for receiving said signal from said output resonator member and outputting said signal; and
   a conductive tuning member protruding between at least one of said feed lines and an inner surface of said conductive housing such that said conductive tuning member affects a capacitance of said at least one of said feed lines.

2. A filter according to claim 1, comprising two conductive tuning members one protruding between said output feed line and an inner surface of said conductive housing thereby affecting a capacitance of said output feed line and one protruding between said input feed line and an inner surface of said conductive housing thereby affecting a capacitance of said input feed line.

3. A filter according to claim 1 or 2, wherein said conductive tuning member is a movable tuning member configured to move such that a distance that said protruding member extends from said inner surface of said conductive housing can be varied, said capacitance of said at least one feed line affected by said protruding member varying with said distance and thereby changing a bandwidth of said filter.

4. A filter according to claim 3, wherein said tuning member comprises a screw extending from said inner surface of said conductive housing towards said at least one feed line.

5. A filter according to any preceding claim, said filter being at least one of a radio frequency filter and a combline filter.

6. A filter according to any preceding claim, wherein said input and output feed lines run substantially perpendicular

to a longitudinal access of said resonant members from an inner surface of said housing to abut against said input and output resonant members respectively, said conductive tuning member extending from a same inner surface of said housing or from an adjacent inner surface as said feed line extends from and wherein a plane that passes through said longitudinal access of said resonant member and said feed line passes through said tuning member.

7. A filter according to any one of claims 1 to 5, wherein a first portion of said feed lines extends substantially perpendicular to a longitudinal access of said resonant members towards said respective resonant members from an inner wall of said housing running parallel to said longitudinal access and a second portion located towards but at a distance from said respective resonant members extends substantially parallel to said longitudinal access, said conductive tuning member extending from one of said inner walls of said housing on a same side of said resonant member as said feed line.

8. A filter according to any one of claims 1 to 5, wherein said feed lines run substantially parallel to a longitudinal access of said resonant members, said conductive tuning member extending from a surface of an inner wall of said housing, said feed line lying between said surface of said inner wall from which said conductive tuning member extends and said resonant member.

9. A filter according to any preceding claim wherein said plurality of resonant members are each mounted within a respective resonant chamber, said resonant chambers being formed by walls of said housing and partition walls within said housing, at least some of said partition walls not extending between opposing walls of said housing such that said resonant chambers are not completely isolated from each other by said partition walls.

10. A filter according to any preceding claim, wherein said housing contains a granular dielectric material such that said plurality of resonant members are surrounded by said granular dielectric material.

11. A filter according to claim 10, wherein the dielectric material has at least one of a relative dielectric constant in the range 2 to 10 and a loss tangent at least approximately in the range 4×10^{-4} to 4×10^{-5}.

12. A filter according to any one of claim 10 or 11, wherein the dielectric material is one of a manufactured dielectric powder and granular fused quartz.

13. A method of adjusting a bandwidth of a bandpass filter, said bandpass filter comprising: a plurality of resonator members comprising an input resonator member and an output resonator member each of said plurality of resonator members being mounted on a surface within a conductive housing; an input feed line configured to transmit a signal to said input resonator member such that said signal excites said input resonator member, said plurality of resonator members being arranged such that said signal is transferred between said plurality of resonator members to an output resonator member; an output feed line for receiving said signal from said output resonator member and outputting said signal; and a conductive tuning member protruding between at least one of said feed lines and an inner surface of said conductive housing; said method comprising
moving said conductive tuning member such that a distance that it protrudes from said inner surface of said conductive housing towards at least one feed line changes, a bandwidth of said filter changing in response to said change.

14. A method of constructing a filter with a desired bandwidth comprising:

arranging a plurality of resonator members comprising an input resonator member and an output resonator member on a surface within a conductive housing in such a way that a signal exciting said input resonator is transferred between said plurality of resonator members to an output resonator member;
introducing an input feed line into said housing to transmit a signal to said input resonator member such that said signal excites said input resonator member;
introducing an output feed line into said housing to receive a signal from said output resonator member;
introducing a conductive tuning member to protrude between at least one of said feed lines and an inner surface of said conductive housing, said protruding member affecting a capacitance of said at least one feed line; and
adjusting a distance that said conductive tuning member protrudes from said inner surface of said housing towards said at least one feed line to attain a desired bandwidth for said filter.

15. A method according to claim 14, comprising a further step performed prior to adjusting said distance that said conductive tuning member protrudes, of at least partially filling said housing with a granular dielectric material.

Amended claims in accordance with Rule 137(2) EPC.

1. A filter (5) comprising:

   a plurality of resonator members (30) comprising an input resonator member and an output resonator member each of said plurality of resonator members being mounted on a surface within a conductive housing (10);
   an input feed line (2) configured to transmit a signal to said input resonator member such that said signal excites said input resonator member, said plurality of resonator members being arranged such that said signal is transferred between said plurality of resonator members to an output resonator member;
   an output feed line (22) for receiving said signal from said output resonator member and outputting said signal; and
   a conductive tuning member (40) protruding between at least one of said feed lines (20, 22) and an inner surface of said conductive housing (10) such that said conductive tuning member affects a capacitance of said at least one of said feed lines (20, 22); wherein
   said conductive housing (10) contains a granular dielectric material such that said plurality of resonant members are surrounded by said granular dielectric material.

2. A filter (5) according to claim 1, comprising two conductive tuning members (40)once protruding between said output feed line (22) and an inner surface of said conductive housing (10) thereby affecting a capacitance of said output feed line (22) and one protruding between said input feed line(20) and an inner surface of said conductive housing (10) thereby affecting a capacitance of said input feed line (20).

3. A filter (5) according to claim 1 or 2, wherein said conductive tuning member (40) is a movable tuning member configured to move such that a distance that said protruding member extends from said inner surface of said conductive housing can be varied, said capacitance of said at least one feed line affected by said protruding member varying with said distance and thereby changing a bandwidth of said filter.

4. A filter (5) according to claim 3, wherein said tuning member comprises a screw extending from said inner surface of said conductive housing towards said at least one feed line.

5. A filter according to any preceding claim, said filter being at least one of a radio frequency filter and a combline filter (5).

6. A filter(5) according to any preceding claim, wherein said input and output feed lines (20, 22) run substantially perpendicular to a longitudinal access of said resonant members from an inner surface of said housing to abut against said input and output resonant members respectively, said conductive tuning member extending from a same inner surface of said housing or from an adjacent inner surface as said feed line extends from and wherein a plane that passes through said longitudinal access of said resonant member and said feed line passes through said tuning member.

7. A filter according to any one of claims 1 to 5, wherein a first portion of said feed lines extends substantially perpendicular to a longitudinal access of said resonant members towards said respective resonant members from an inner wall of said housing running parallel to said longitudinal access and a second portion located towards but at a distance from said respective resonant members extends substantially parallel to said longitudinal access, said conductive tuning member extending from one of said inner walls of said housing on a same side of said resonant member as said feed line.

8. A filter (5) according to any one of claims 1 to 5, wherein said feed lines (20, 22) run substantially parallel to a longitudinal access of said resonant members, said conductive tuning member extending from a surface of an inner wall of said housing, said feed line lying between said surface of said inner wall from which said conductive tuning member (40) extends and said resonant member (30).

9. A filter according to any preceding claim wherein said plurality of resonant members (30) are each mounted within a respective resonant chamber, said resonant chambers being formed by walls of said housing and partition walls within said housing, at least some of said partition walls not extending between opposing walls of said housing such that said resonant chambers are not completely isolated from each other by said partition walls.

10. A filter (5) according to any preceding claim, wherein the dielectric material has at least one of a relative dielectric constant in the range 2 to 10 and a loss tangent at least approximately in the range 4×10^{-4} to 4×10^{-5}.

11. A filter (5)according to any one preceding claim, wherein the dielectric material is one of a manufactured dielectric powder and granular fused quartz.

12. A method of constructing a filter with a desired bandwidth comprising:

arranging a plurality of resonator members comprising an input resonator member and an output resonator member on a surface within a conductive housing in such a way that a signal exciting said input resonator is transferred between said plurality of resonator members to an output resonator member;
introducing an input feed line into said housing to transmit a signal to said input resonator member such that said signal excites said input resonator member;
introducing an output feed line into said housing to receive a signal from said output resonator member;
at least partially filling said housing with a granular dielectric material;
introducing a conductive tuning member to protrude between at least one of said feed lines and an inner surface of said conductive housing, said protruding member affecting a capacitance of said at least one feed line; and
adjusting a distance that said conductive tuning member protrudes from said inner surface of said housing towards said at least one feed line to attain a desired bandwidth for said filter.

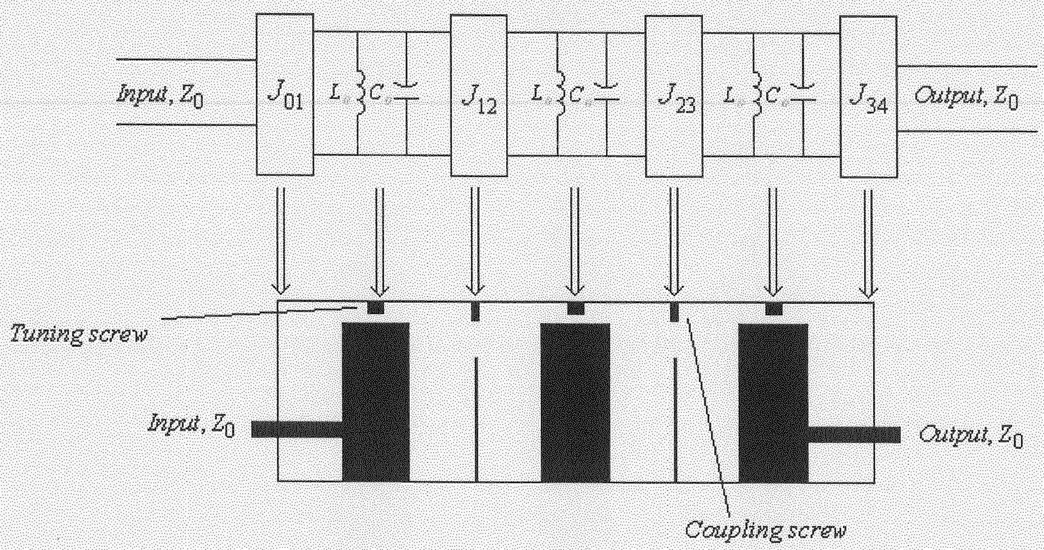

Figure 1a

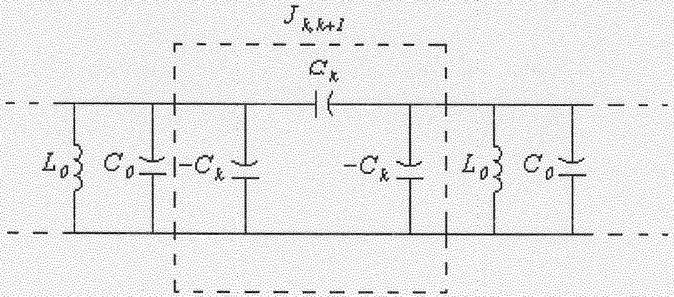

Figure 1b

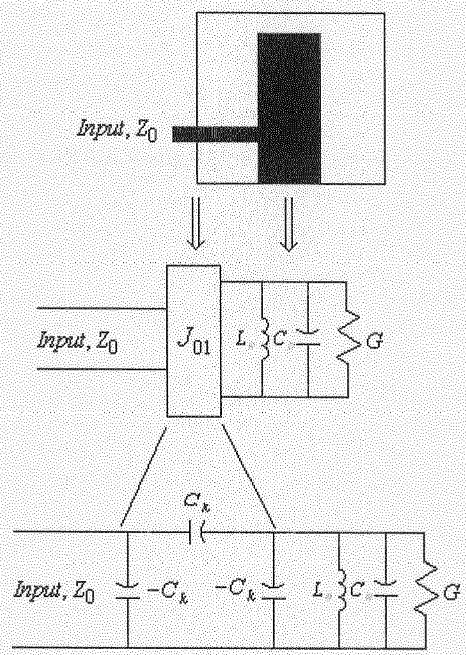

Figure 2

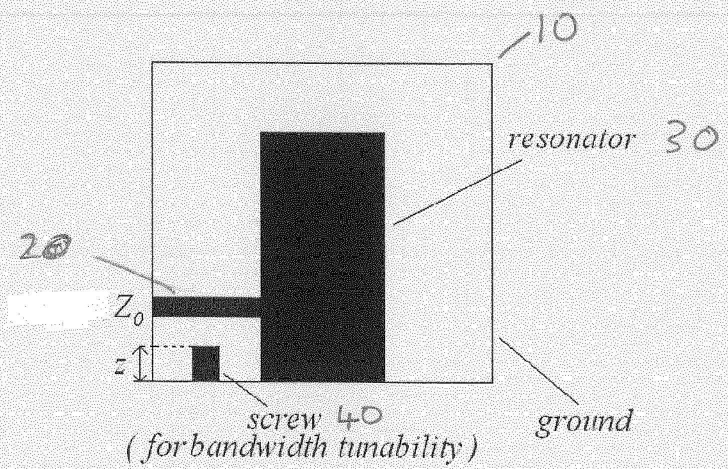

Figure 3

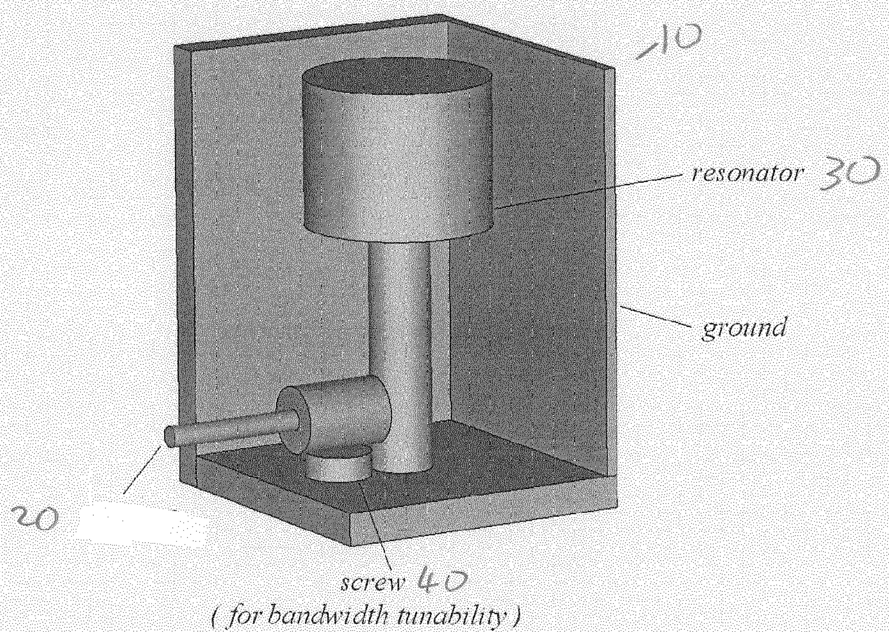

Figure 4

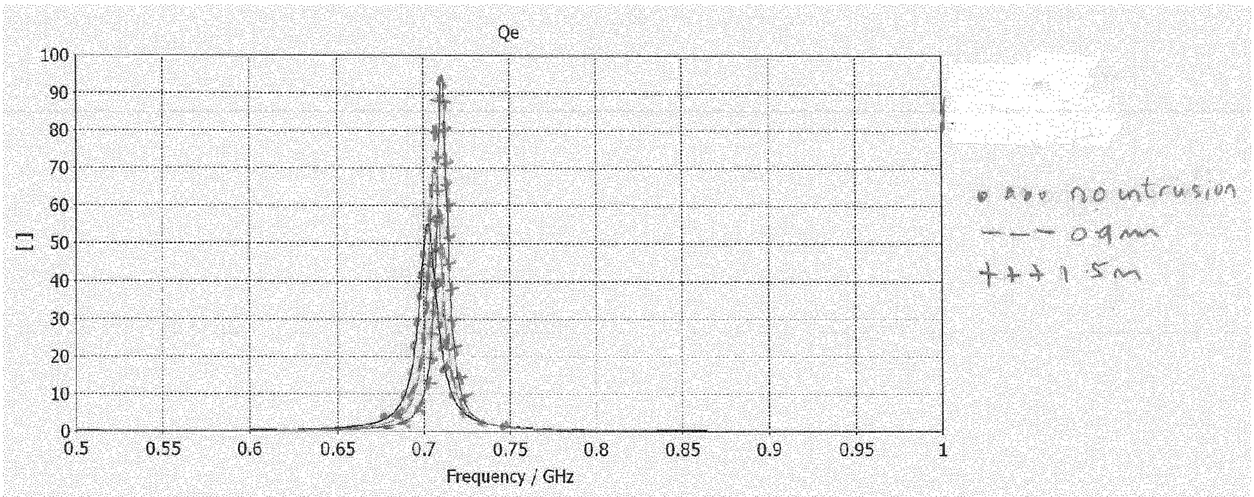

Figure 5

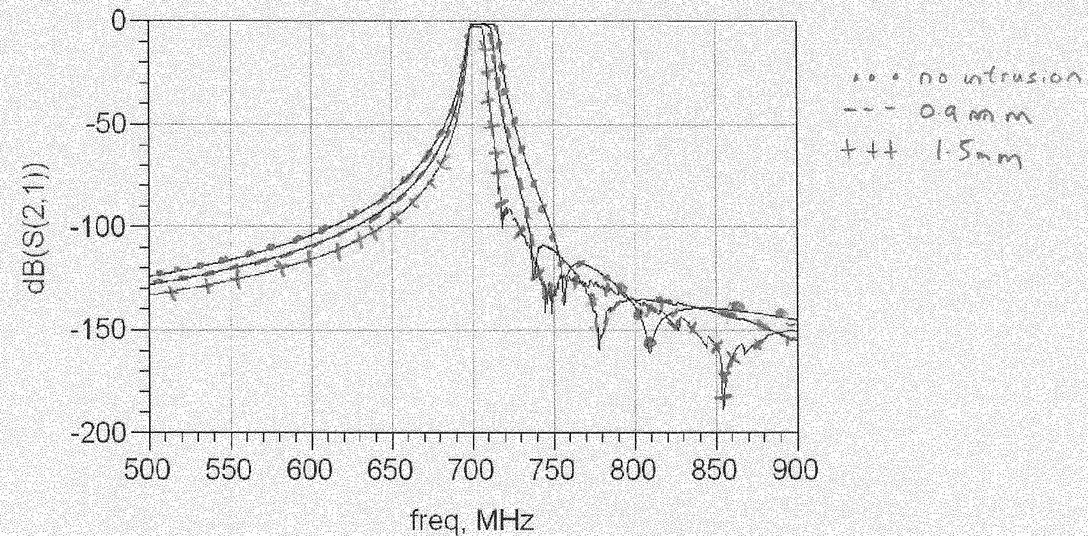

Figure 6

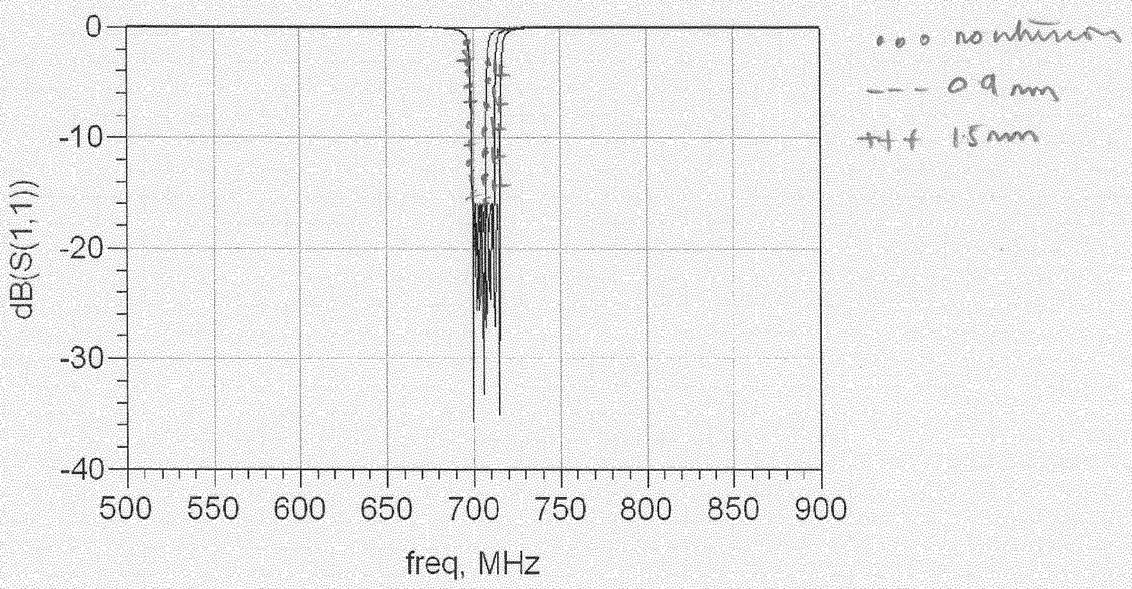

Figure 7

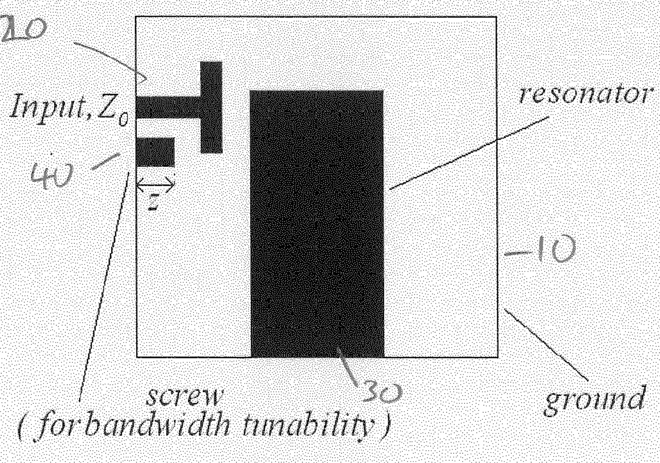

Figure 8

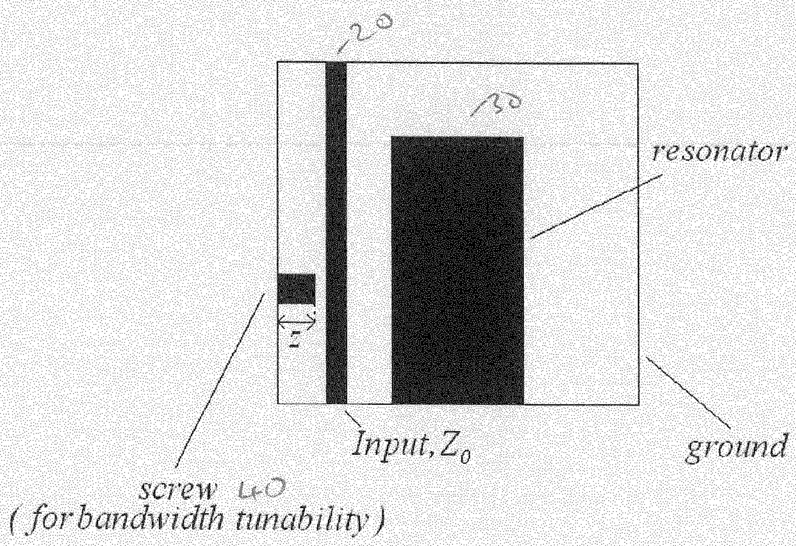

Figure 9

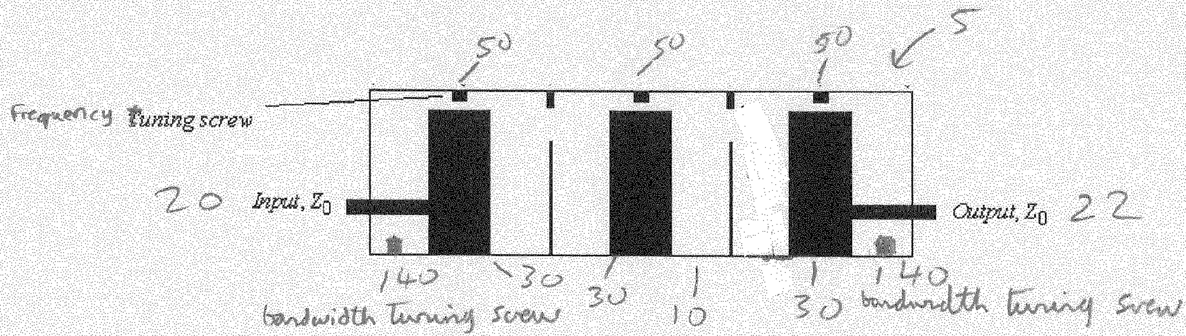

Figure 10

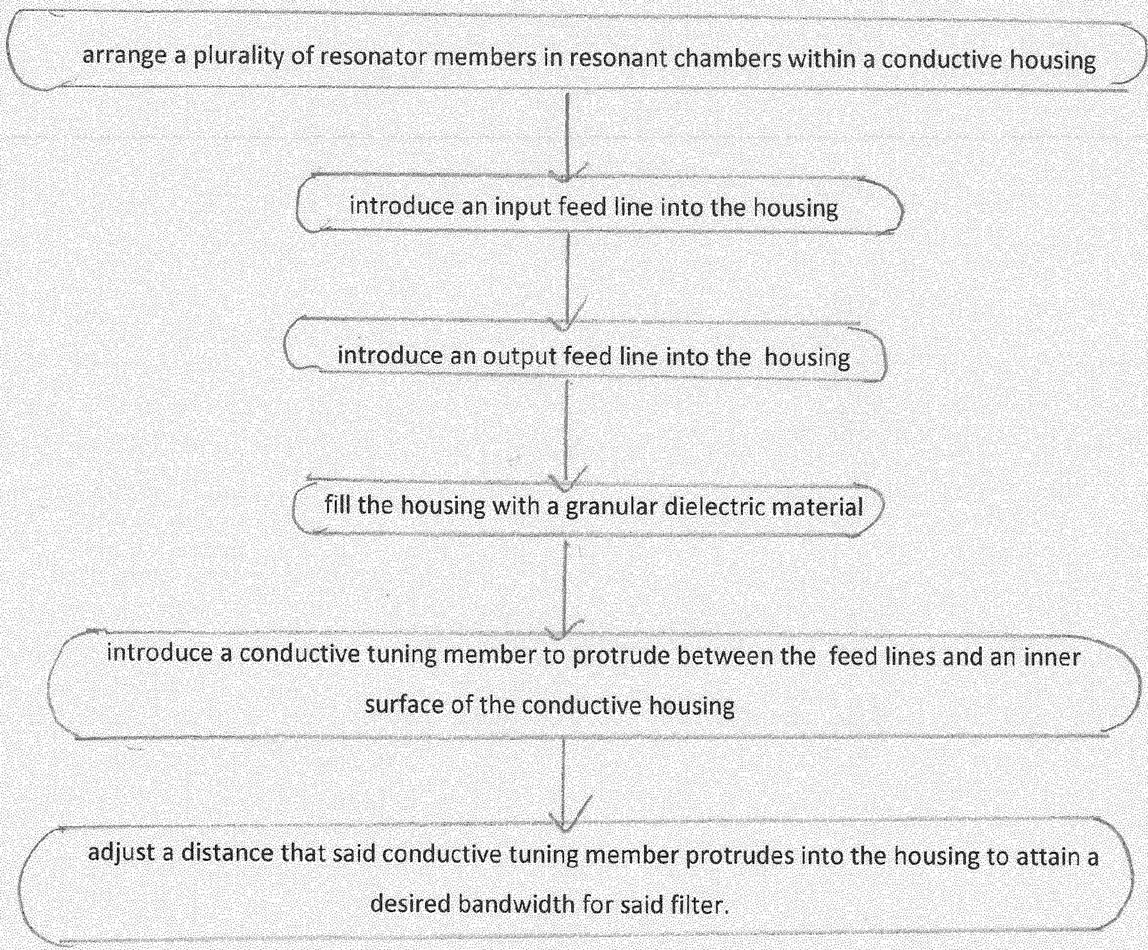
arrange a plurality of resonator members in resonant chambers within a conductive housing
introduce an input feed line into the housing
introduce an output feed line into the housing
fill the housing with a granular dielectric material
introduce a conductive tuning member to protrude between the feed lines and an inner surface of the conductive housing
adjust a distance that said conductive tuning member protrudes into the housing to attain a desired bandwidth for said filter.

Figure 11

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EUROPEAN SEARCH REPORT

Application Number
EP 14 30 5063

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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	18 June 2014	Unterberger, Michael

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