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## (54) CERAMIC FILTER APPARATUS AND METHOD OF USE THEREOF

(57) A ceramic filter apparatus is provided including at least one ceramic body portion having one or more resonating means defined therein. At least part of said ceramic body portion has an outer electrically conductive coating or surface provided or formed thereon. At least a portion of said outer electrically conductive coating or surface is arranged to provide one or more walls of a housing for one or more electronic or radio frequency (RF) components provided in the apparatus in use.

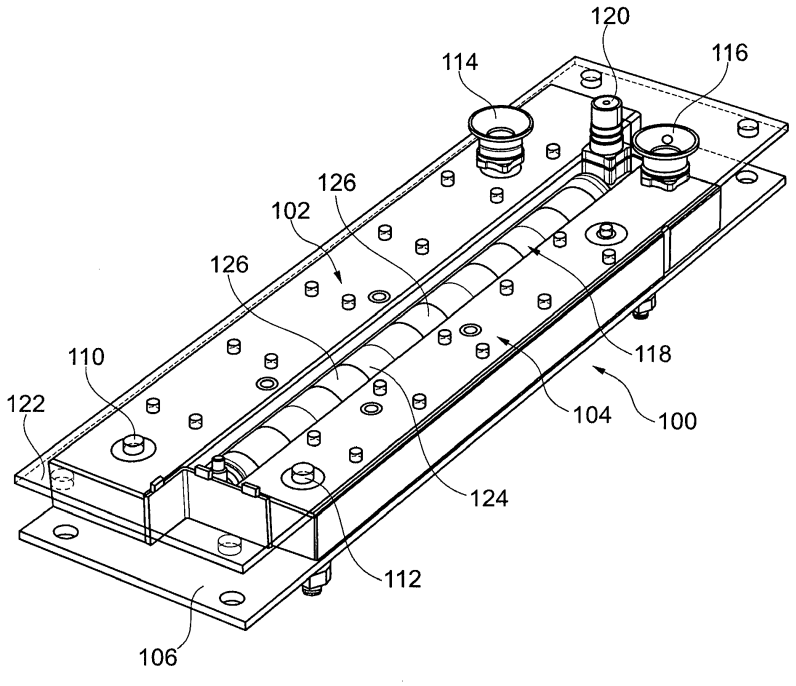


Fig. 7

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## Description

**[0001]** This invention relates to ceramic filter apparatus and to a method of use thereof.

**[0002]** A conventional telecommunication cell site arrangement will typically include at least one base transceiver station (BTS) to transmit and receive radio frequency signals via a mast mounted antenna to mobile electronic devices. Transmission and receive radio frequency signals typically pass along coaxial cables between the BTS and the antenna. The technology within BTSs has advanced significantly and for many of the constituent modules, has also reduced in size considerably. The size reduction has meant that some of the equipment that previously occupied a ground based rack at the base of the mast, is now sufficiently compact to be housed in a single box known as a remote radio head (RRH), which can be mounted at the top of the cell site mast. A vital component of any BTS/RRH is a front end filter. The front end filter can take the form of a bandpass filter for time divisional duplex systems (TDD, meaning that the system transmits and receives radio frequency signals on the same frequency but at different times) or a diplexer for frequency division duplex systems (FDD, meaning that the system is capable of transmitting and receiving radio frequency signals simultaneously but at different frequencies). An example of a conventional front end transmit/receive diplexer 2 is shown in figure 1. Tx represents the transmission path from a BTS for transmitting one or more radio frequency signals to the antenna (ANT), and Rx represents the receive path to a BTS for receiving one or more radio frequency signals from the antenna (ANT). Transmit and receive filters 4, 6 respectively are provided in the transmission and receive paths respectively.

**[0003]** Filters are electronic devices which allow an electromagnetic wave to be transmitted therethrough. They are designed in such a manner so as to allow radio frequency signals at one or more pre-determined frequencies to pass through the device (passband frequencies) and to substantially prevent radio frequency signals at frequencies other than the one or more pre-determined frequencies from passing through the device (stop band frequencies). An example of a typical frequency response for the transmit and receive filters 4, 6 shown in figure 1, is illustrated in figure 2. The graph shows the transmission loss (dB) with frequency (MHz) for the receive filter passband (Rx) and the transmit filter passband (Tx) in this example. It can be seen that the transmission loss is high for each filter when the frequency is close to, but not in, the passband frequency. However, at frequencies much higher than the passband frequency of the filters, the transmission loss decreases, as shown in Figure 3. Thus, there is an increase in unwanted frequencies passing through the filters at higher radio frequencies with respect to the passband frequency, which is undesirable.

**[0004]** In an attempt to overcome this problem, it is known to provide a low pass filter (LPF) 8 in the cell site arrangement 2 between the antenna (ANT) and the Rx and Tx filters 4, 6, as shown in figure 4, to clean up the high frequency response. The LPF frequency response is shown in figure 5b, where it can be seen that the transmission loss of the LPF increases with increasing frequency. When this frequency response is combined with the undesirable frequency response shown in figure 3, the resulting frequency response is shown in figure 5a, thereby solving the problem of unwanted frequencies passing through the Rx and Tx filters 4, 6 at high frequencies.

**[0005]** Figure 6 shows an example of a practical implementation of the LPF in a conventional filter arrangement 10. The filter 10 comprises a housing 12 having a base 14, and side walls 16 defining an opening at a top edge 18 thereof. The housing 12 has a common port 20 and four channel ports 22. A plurality of resonating cavities 24 are defined within the housing 12 and a plurality of resonator posts 26 are provided in the cavities to resonate at one or more desired frequencies. In this example, a trough 28 is integrally formed within the housing adjacent the peripheral edge thereof to house the LPF. The integral trough 28 is provided with an electrically conductive surface or coating thereon in use and acts as an outer electrical conductor to form part of the LPF. An inner electrical conductor 30 is suspended within the trough 28. Insulating means in the form of polytetrafluroethylene (PTFE) sleeves 32 are located at spaced apart intervals on inner electrical conductor 30 in trough 28 so as to ensure that a space is maintained between the inner and outer electrical conductors 30, 28 respectively. Although this LPF arrangement is effective in producing the desired filter response, it requires its own integral trough within the filter housing which takes up valuable space within the apparatus and restricts the design of the filter. There is therefore a requirement to provide alternative filter technology that is smaller in size and has a greater degree of flexibility in its design compared to conventional filter technology, while maintaining the filter performance.

**[0006]** It is known to use ceramic filters to provide a more compact filter design. Ceramic filters are typically formed from a solid block of high permittivity low-loss ceramic, the exterior surface of which is coated in an electrically conductive material, such as metal. The ceramic is typically formed by pressing and firing, and is then coated in a high electrical conductivity adhesive paint.

**[0007]** It is therefore an aim of the present invention to provide ceramic filter apparatus that overcomes the abovementioned problems.

**[0008]** It is a further aim of the present invention to provide a method of using ceramic filter apparatus that overcomes the abovementioned problems.

**[0009]** According to a first aspect of the present invention there is provided ceramic filter apparatus, said apparatus including at least one ceramic body portion hav-

ing one or more resonating means defined therein, and at least part of said ceramic body portion having an outer electrically conductive coating or surface provided or formed thereon, and wherein at least a portion of said outer electrically conductive coating or surface is arranged to provide one or more walls of a housing for one or more electronic or radio frequency (RF) components provided in the apparatus in use.

**[0010]** Thus, the present invention utilises the electrical conductive coating or surface on the exterior of at least one ceramic body portion of the filter apparatus already present to provide a housing or shield for a further electronic or RF component provided in the apparatus, (such as for example a filter or filter means) thereby avoiding or reducing the number of additional housing components to be provided for housing said electronic or RF components. This reduces the cost of the filter apparatus, reduces the size of the filter apparatus and increases the flexibility of the apparatus design. In particular, in one example, utilisation of the electrical conductive outer surface of at least a portion of the ceramic body portion removes the requirement for a specific trough to be provided in a housing of the filter for a low pass filter (LPF) to be located therein.

**[0011]** The advantage of ceramic filters is that the electromagnetic field is located entirely, or substantially entirely, within the ceramic body portion and does not extend to the outermost metallic or electrically conductive layer or coating provided on the filter's body portion. Any electrical current flowing through the metallic or electrically conductive layer or coating on a ceramic filter body portion, that is associated with the filter itself, is adjacent the inner surface of the layer or coating only, typically 5-10$\mu$m of the same, and is often referred to as the "skin effect". As such, the present applicants have utilised this fact to make use of the outermost surface of the metallic or electrically conductive layer or coating on the ceramic body portion for a further functional purpose within the filter apparatus. In particular, the present applicants have arranged the ceramic body portion(s) within the apparatus to act as shielding means for one or more other electronic or RF components within the apparatus.

**[0012]** The outer surface of the ceramic body portion typically acts directly, solely or as at least part of the closest housing or shield for said electronic or RF component.

**[0013]** In one embodiment preferably two, or at least two, ceramic body portions are provided. The two, or at least two, ceramic body portions are typically arranged a spaced distance apart to at least partially define a trough, recess, channel or housing therebetween.

**[0014]** Preferably the ceramic body portion is arranged to act as a ceramic filter or ceramic filter means.

**[0015]** Preferably the at least second ceramic body portion has one or more resonating means defined therein.

**[0016]** Preferably the, or each, ceramic body portion is rectangular, or substantially rectangular in shape. The body portion therefore typically has a plurality of relatively long edges defining a plurality of elongate side walls therebetween and a plurality of relatively shorter edges defining end walls therebetween.

**[0017]** Preferably one or more side walls of said ceramic body portions forms at least a part or whole of a wall of a trough, recess, channel or housing for the electronic or RF component for location therein in use. However, it will be appreciated that one or more end walls of the ceramic body portions could be used to form a wall of the trough, recess or housing if required.

**[0018]** In the embodiment where there are two or more ceramic body portions provided, preferably one or more side walls of each ceramic body portion forms at least part or whole of a wall of the trough, recess, channel or housing.

**[0019]** Preferably at least one of the ceramic body portions is arranged to act as a transmission filter or filter means for allowing the transmission of one or more transmit RF signals therethrough in use.

**[0020]** Preferably at least one of the ceramic body portions is arranged to act as a receiving filter or filter means for allowing the receiving of one or more receive RF signals therethrough in use.

**[0021]** Preferably the two, or at least two, ceramic body portions are arranged parallel or substantially parallel, within the apparatus. Thus, in one example, longitudinal axes of each ceramic body portion are parallel or substantially parallel.

**[0022]** Preferably the one or more ceramic body portions are arranged on a base member. The base member is typically formed from or includes an electrically conductive material and/or at least part of which is provided with an electrically conductive outer layer or coating thereon. Thus, a combination of the base member and one or more walls of the one or more ceramic body portions defines a housing, trough, channel or recess therebetween for the location of the electronic or RF component(s).

**[0023]** In one embodiment the base member is or includes a printed circuit board (PCB).

**[0024]** In one embodiment a lid, top, cover or closure member is provided to close an opening defined between the one or more walls of the one or more ceramic body portions and/or optionally the base member or PCB.

**[0025]** Preferably the lid, top or closure member is formed from or includes an electrically conductive material and/or is provided with an electrically conductive layer or coating on a surface facing inwardly of the space defined as the housing for the one or more electronic components or RF components.

**[0026]** In one example the lid, top or closure member is or includes a printed circuit board (PCB).

**[0027]** The advantage of using one or more PCBs as a base member and/or top member of the defined housing, trough or recess is that it can be used to connect to one or more further electronic components, connection means, tuning means, tuning screws and/or the like.

**[0028]** The base and/or top member can be attached

to the one or more ceramic body portions or a further housing by soldering, adhesive, engagement means and/or the like. The engagement means can include one or more nuts and bolts, screws, inter-engaging members, clips and/or the like.

**[0029]** In one embodiment the electronic or RF component located within the defined housing, recess, channel or trough is a low pass filter (LPF) or forms a low pass filter in combination with the ceramic portion walls, base member and/or top member.

**[0030]** Preferably the one or more electronic or RF components located within the housing is arranged to be a spaced distance apart from the outer walls of the ceramic body portion and/or other walls defining the component housing, recess, channel or trough.

**[0031]** In one embodiment electrical insulating means are provided to maintain a spaced distance between the electronic or RF component, or at least part of the electronic or RF component, and one or more walls of the ceramic body portion and/or other walls defining the component housing, recess or trough.

**[0032]** In one example the electrical insulating means is in the form of a sleeve member, such as for example a polytetrafluoroethylene (PTFE) sleeve member.

**[0033]** Thus, in the example where a low pass filter is provided between two or more ceramic body portions and a base member, insulating means can be provided to ensure the inner electrical conducting means of the low pass filter does not contact the walls of the ceramic body portion acting as the outer electrical conducting means for the low pass filter or the base member. The insulating means can be joined by friction fit within the defined housing, recess, channel and/or trough or can be joined by suitable insulating attachment means, such as one or more screws, inter-engaging members, clips, nuts and bolts and/or the like.

**[0034]** In one embodiment one or more recesses are defined in the one or more ceramic body portions, and the walls defining the one or more recesses define a housing, trough, channel or recess for the location of the electronic or RF component therein in use. The walls of the ceramic portion recesses are provided with the electrically conductive surface or coating thereon.

**[0035]** In one example the electronic or RF component is in the form of an amplifier or amplification means. The amplifier or amplification means typically amplifies one or more RF signals in use.

**[0036]** Preferably the at least one ceramic body portion is arranged to act as a filter or filter means in use. Thus, the ceramic body portion typically allows the passage of one or more RF signals therethrough at at least one frequency or frequency ranges but prevents, or substantially prevents, the passage of one or more RF signals therethrough at other frequencies different, or substantially different, to the at least one frequency or frequency ranges.

**[0037]** In the embodiment where two or more ceramic body portions are provided, each ceramic body portion is arranged to act as a filter or filter means in use. In one example, one of the ceramic filter means/body portions allows the passage of one or more RF signals therethrough at a first frequency or frequency range and the at least one other ceramic filter means/body portions allows the passage of one or more RF signals therethrough at at least a second frequency or frequency range. The at least second frequency or frequency range is different, or substantially different, to the first frequency or frequency range.

**[0038]** It is to be noted that the at least first frequency ranges and/or the at least second frequency ranges could be contiguous or non-contiguous in the frequency spectrum.

**[0039]** The resonating means or sections defined within the ceramic body portion are capable of resonating at such electromagnetic frequency or frequencies so as to provide a required electromagnetic frequency response of the filter.

**[0040]** Preferably each resonating means is substantially cuboid in shape.

**[0041]** In one embodiment each resonating means has at least one tuning means provided or associated therewith.

**[0042]** The ceramic body portion can be formed from a substantially continuous and/or solid block of ceramic material. Alternatively, two or more substantially solid and/or continuous blocks of ceramic material could be joined or arranged together to produce a filter having the same function and/or performance if required.

**[0043]** Preferably the entire exterior surface, or substantially the entire exterior surface, of the ceramic body portion, or at least the external area of the filter in which the resonating means are provided, is metallised and/or is provided with an electrically conductive material, layer(s) and/or coating(s) thereon.

**[0044]** Preferably the ceramic material used in the filter body is a high permittivity ceramic material.

**[0045]** Preferably the high permittivity ceramic material has a permittivity of between approximately 10-100$\varepsilon$.

**[0046]** Preferably the filter apparatus and/or the ceramic body portion includes input coupling means and output coupling means. The input coupling means is/are typically coupled to the first resonating means of each ceramic filter means and allows for the input of an electromagnetic wave therethrough. The output coupling means is/are typically coupled to the last resonating means of the each ceramic filter means and allows for the output of an electromagnetic wave therefrom.

**[0047]** Preferably the one or more electronic or radio frequency components are electrically connected to and/or electromagnetically coupled to at least part of the at least one ceramic body portion.

**[0048]** Preferably the ceramic filter apparatus is ceramic waveguide filter apparatus.

**[0049]** Preferably the ceramic filter apparatus is provided in its own housing or outer housing. The outer housing of the ceramic filter apparatus is separate to and dif-

ferent to the housing defined by one or more walls of the ceramic body portion for the one or more electronic or RF components.

**[0050]** Thus, the present invention utilises the outer electrically conductive surface of a ceramic filter to provide a shield for one or more electronic components to protect the components from other electromagnetic fields present in the apparatus.

**[0051]** According to a second aspect of the present invention there is provided a method of using ceramic filter apparatus, said apparatus including at least one ceramic body portion having one or more resonating means defined therein, and at least part of said ceramic body portion having an outer electrically conductive coating or surface provided or formed thereon, and wherein said method includes the step of using at least a portion of said outer electrically conductive coating or surface to provide one or more walls of a housing for one or more electronic or radio frequency (RF) components provided in the apparatus.

**[0052]** According to a third aspect of the present invention there is provided a telecommunication cell site arrangement including ceramic filter apparatus. Preferably the cell site arrangement can include any or any combination of one or more antenna, masts, base transceiver stations (BTSs), remote radio heads (RRHs), coaxial cables, combiners and/or the like.

**[0053]** According to a fourth aspect of the present invention there is provided a method of using a telecommunication cell site arrangement including ceramic filter apparatus.

**[0054]** Embodiments of the present invention will now be described with reference to the following drawings, wherein:

Figure 1 (PRIOR ART) shows an example of a conventional front end transmit/receive diplexer unit that could be used in a conventional telecommunication cell site arrangement;

Figure 2 (PRIOR ART) shows an example of a typical frequency response for the diplexer unit shown in Figure 1;

Figure 3 (PRIOR ART) shows an example of a typical frequency response for the diplexer unit shown in Figure 1 at relatively higher frequencies to the frequencies shown in Figure 2;

Figure 4 (PRIOR ART) shows an example of a conventional front end transmit/receive diplexer unit that could be used in a conventional telecommunication cell site arrangement including a low pass filter to clean up any unwanted high frequency response;

Figures 5a and 5b (PRIOR ART) shows an example of a typical frequency response for the diplexer unit shown in Figure 4, and a typical frequency response for a low pass filter per se respectively;

Figure 6 (PRIOR ART) shows an example of a practical implementation of a low pass filter in a conventional filter arrangement;

Figure 7 shows a perspective view of ceramic waveguide filter apparatus according to an embodiment of the present invention with a low pass filter;

Figure 8 shows a plan view from above of the ceramic waveguide filter apparatus in figure 7 with the lid removed; and

Figure 9 shows a perspective view of ceramic waveguide filter apparatus according to a further embodiment of the present invention.

**[0055]** Referring firstly to Figures 7-8, there is illustrated ceramic filter apparatus in the form of a ceramic waveguide diplexer unit 100 according to an embodiment of the present invention.

**[0056]** Diplexer unit 100 consists of two ceramic waveguide filters 102, 104, the longitudinal axes of which are arranged parallel to each other, attached in a spaced apart manner to a base member in the of a PCB 106.

**[0057]** Ceramic filter 102 is arranged to act as a transmission filter for allowing the passage of one or more RF signals therethrough at at least a first frequency or frequency range, but to prevent, or substantially prevent, the passage of one or more RF signals therethrough at one or more other frequencies different to the at least first frequency or frequency range.

**[0058]** Ceramic filter 104 is arranged to act as a receiving filter for allowing the passage of one or more RF signals therethrough at at least a second frequency or frequency range, but to prevent, or substantially prevent, the passage of one or more RF signals therethrough at one or more other frequencies different to the at least second frequency or frequency range.

**[0059]** Each ceramic filter 102, 104 comprises a rectangular ceramic body portion having a plurality of resonating sections defined therein. Each resonating section is capable of resonating at such frequency so as to provide the first and second frequencies or frequencies range responses respectively of the filters.

**[0060]** Each filter 102, 104 has an input coupling connection 110, 112 respectively for allowing the input of one or more RF signals therethrough, and an output coupling connection 114, 116 respectively for allowing the output of one or more RF signals therefrom.

**[0061]** The outer surface of the ceramic body portions of each filter 102, 104 is metallised with at least one layer of metal plate thereon. In accordance with the present invention, the outermost metallised layer of the ceramic body portions is used to at least partially define a housing for the location of a low pass filter (LPF) 118 therein. The LPF 118 is cascaded with the two filters 102, 104 and

the LPF in turn is connected to an antenna of the cell site arrangement via a connection 120.

**[0062]** The housing for the LPF 118 is enclosed and is defined between the two opposing outer side walls of ceramic filters 102, 104, the base 106 and a lid member in the form of a PCB 122 that covers the LPF and the two ceramic filters 102, 104.

**[0063]** The electrically conductive surfaces of the filter side walls, the base 106 and the top 122 defines the walls of the outer conductor for the LPF. An elongate electrically conductive member 124 such as for example a metal rod, is provided to act as the inner conductor for the LPF. Insulating means in the form of a plurality of PTFE sleeves 126 are provided at spaced apart intervals along the inner conductor 124 to maintain the inner and outer conductors a spaced distance apart in use.

**[0064]** Thus, it can be seen that no integrally formed or pre-moulded trough needs to be formed in the apparatus housing for the location of the LPF as is required with conventional filter apparatus. The present invention therefore has the advantage that it uses a reduced number of components, the size of the resulting filter apparatus can be made smaller and there is greater flexibility as to where the LPF can be located in the apparatus.

**[0065]** Referring to figure 9, there is illustrated a further embodiment of the present invention wherein a recess 200 is defined in a base wall of the ceramic filter 102. An electronic component (not shown) can sit within the recess 200 in use and be electrically connected or electromagnetically coupled to the filter 102. The PCB base 106 can form a lid to the recess 200 to wholly or substantially enclose the electronic component when located in the recess. The electronic component can also be attached to the PCB base 106 if required.

## Claims

1. A ceramic filter apparatus, said apparatus including at least one ceramic body portion having one or more resonating means defined therein, and at least part of said ceramic body portion having an outer electrically conductive coating or surface provided or formed thereon, and wherein at least a portion of said outer electrically conductive coating or surface is arranged to provide one or more walls of a housing for one or more electronic or radio frequency (RF) components provided in the apparatus in use.

2. Apparatus according to claim 1 wherein the one or more electronic or radio frequency components include or consist of a filter, a low pass filter (LPF), forms a low pass filter (LPF) in combination with the ceramic outer coating or surface portion, a base member and/or a top member, an amplifier or amplification means.

3. Apparatus according to claim 1 wherein two, or at least two, ceramic body portions are provided; the two, or at least two, ceramic body portions arranged a spaced distance apart to at least partially define a trough, recess, channel or housing therebetween.

4. Apparatus according to claim 1 wherein the, or each, ceramic body portion is rectangular or substantially rectangular in shape, said body portion having a plurality of relatively long edges defining a plurality of side walls therebetween and a plurality of relatively shorter edges defining a plurality of end walls therebetween, one or more side walls of said ceramic body portion forming at least a part or whole of a wall of a trough, recess, channel or housing for location of the electronic or RF component therein in use.

5. Apparatus according to claim 3 wherein at least one of the ceramic body portions is arranged to act as a transmission filter means for allowing the transmission of one or more transmit RF signals therethrough, and at least one of the ceramic body portion is arranged to act as a receiving filter means for allowing the receiving of one or more RF signals therethrough.

6. Apparatus according to claim 3 wherein the two, or at least two, ceramic body portion are arranged parallel or substantially parallel within the apparatus.

7. Apparatus according to claim 1 wherein the one or more ceramic body portions are arranged on a base member, said base member formed from or including an electrically conductive material and/or an electrically conductive outer layer or coating thereon; and/or are arranged on a printed circuit board (PCB).

8. Apparatus according to claim 1 or claim 7 wherein a lid, top, cover or closure means is provided to close an opening defined between one or more walls of the one or more ceramic body portions and/or the base member or PCB, the lid top cover or closure means formed from or including an electrically conductive material and/or an electrically conductive outer later of coating facing inwardly of the space defined as the housing for the one or more electronic or RF components; and/or is a PCB.

9. Apparatus according to claim 1 wherein the one or more electronic or RF components is arranged to be a spaced distance apart from the outer walls of the ceramic body portion and/or electrical insulating means are provided to maintain a spaced distance between the one or more electronic or RF components and one or more walls of the ceramic body portion.

10. Apparatus according to claim 1 wherein one or more recesses are defined in the one or more ceramic

body portions, the walls defining the one or more recesses define a housing, trough, channel or recess for the location of one or more electronic or RF components therein in use.

**11.** Apparatus according to claim 1 wherein the apparatus is in the form of ceramic waveguide apparatus.

**12.** Apparatus according to claim 3 wherein each of the two or more ceramic body portions is arranged to act as a filter or filter means in use, and one of the ceramic body portions allows the passage of one or more radio frequency signals therethrough at at least one frequency or frequency range(s), and at least one other of said ceramic body portions allows the passage of one or more radio frequency signals therethrough at at least a second frequency or frequency range, the first frequency or frequency range being different or substantially different to the at least second frequency or frequency range.

**13.** Apparatus according to claim 1 wherein at least one tuning means is provided or associated with each resonating means.

**14.** Apparatus according to claim 1 wherein the one or more electronic or RF components are electrically connected to and/or electromagnetically coupled to at least part of the at least one ceramic body portion.

**15.** A method of using ceramic filter apparatus, said apparatus including at least one ceramic body portion having one or more resonating means defined therein, and at least part of said ceramic body portion having an outer electrically conductive coating or surface provided or formed thereon, and wherein said method includes the step of using at least a portion of said outer electrically conductive coating or surface to provide one or more walls of a housing for one or more electronic or radio frequency (RF) components provided in the apparatus.

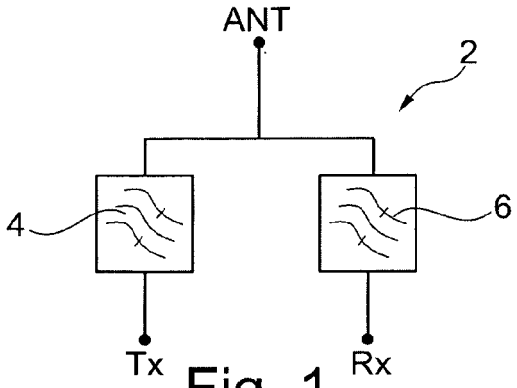


Fig. 1
(PRIOR ART)

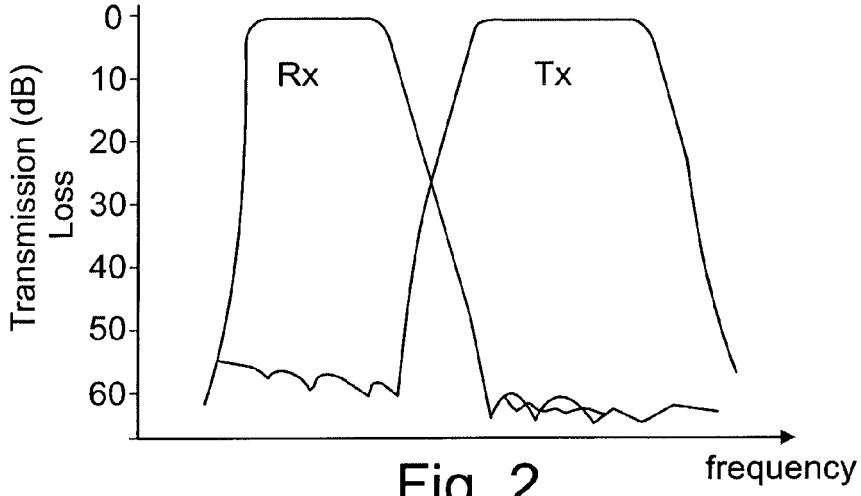


Fig. 2
(PRIOR ART)

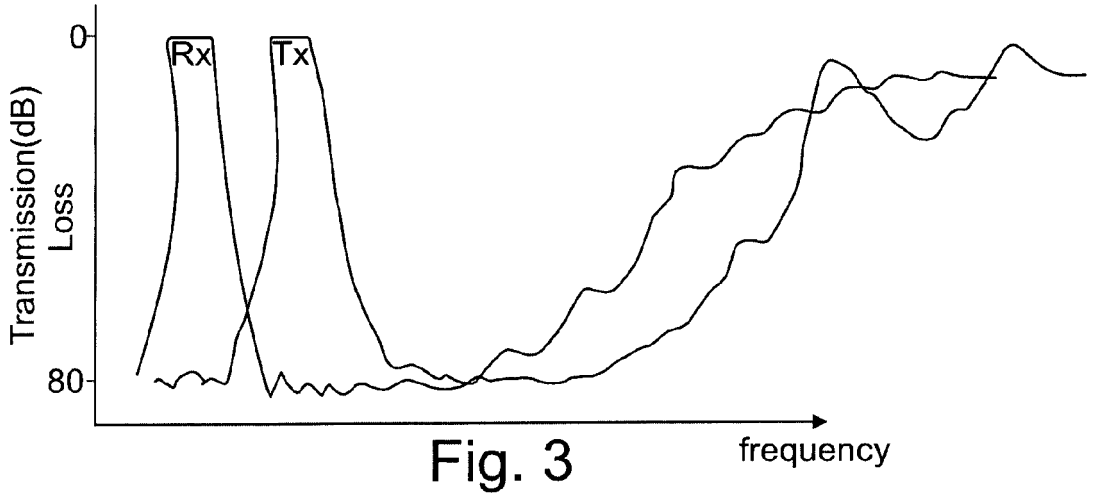


Fig. 3
(PRIOR ART)

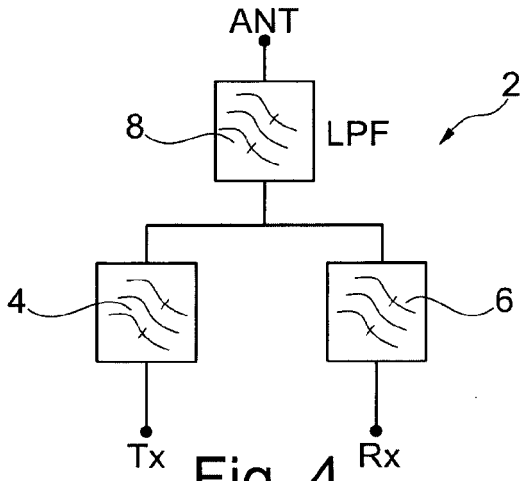


Fig. 4
(PRIOR ART)

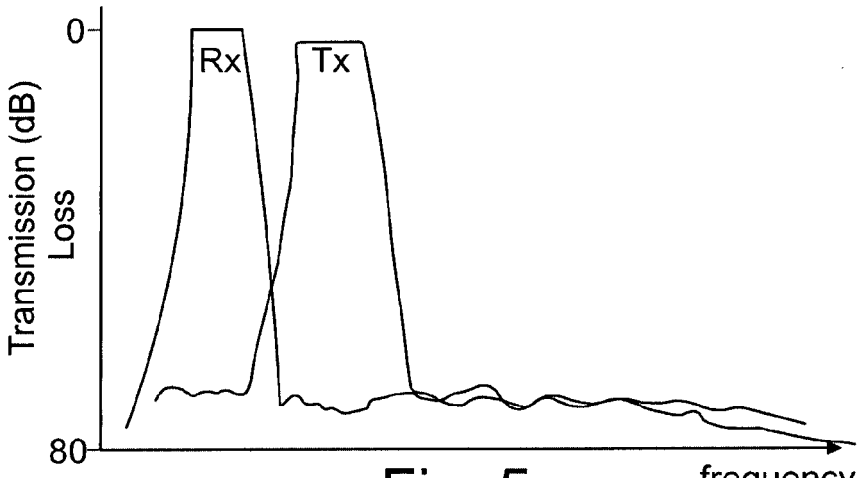


Fig. 5a
(PRIOR ART)

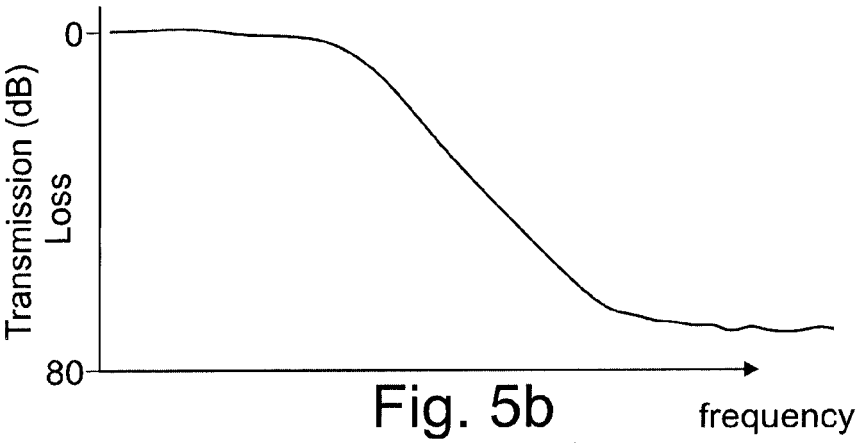


Fig. 5b
(PRIOR ART)

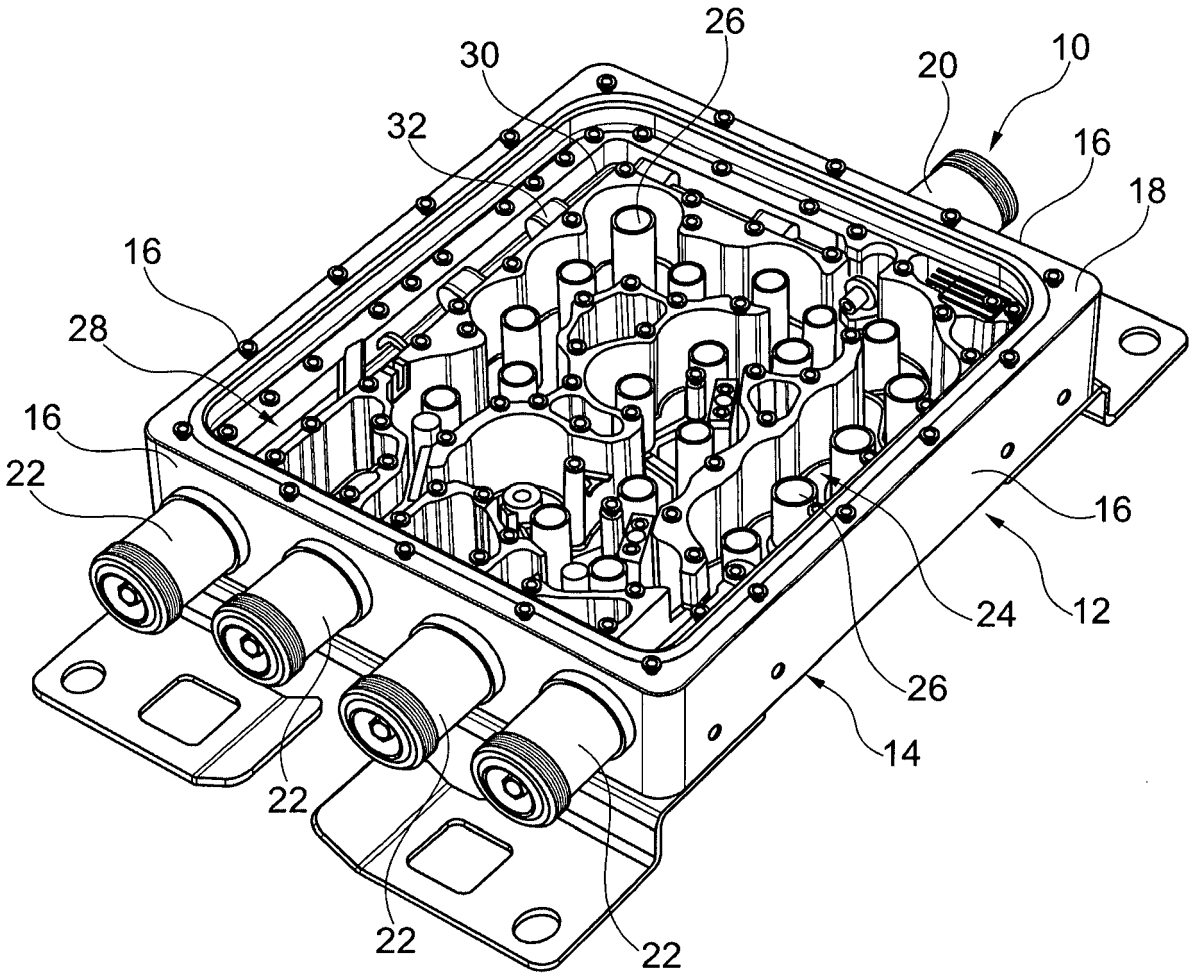


Fig. 6
(PRIOR ART)

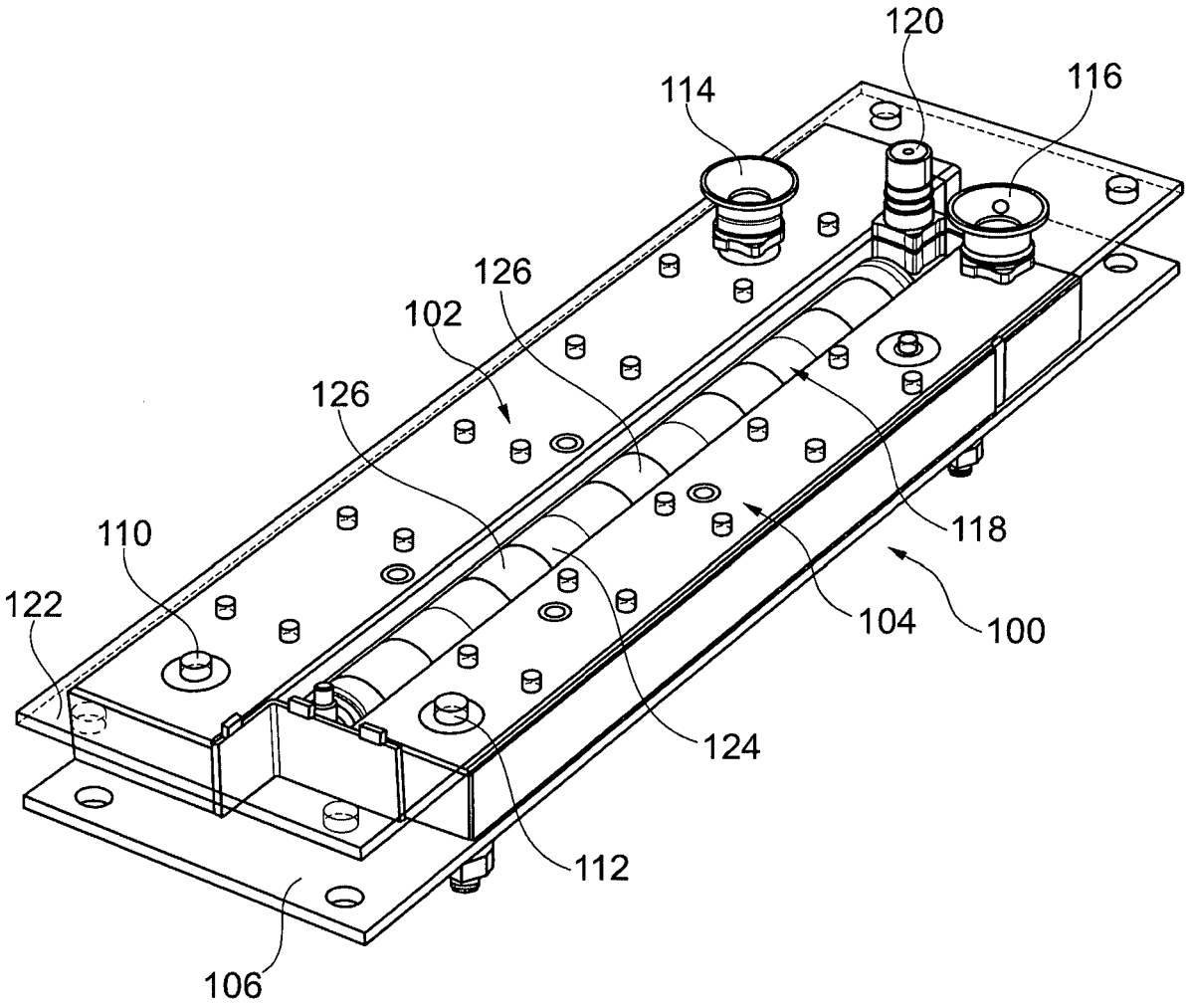


Fig. 7

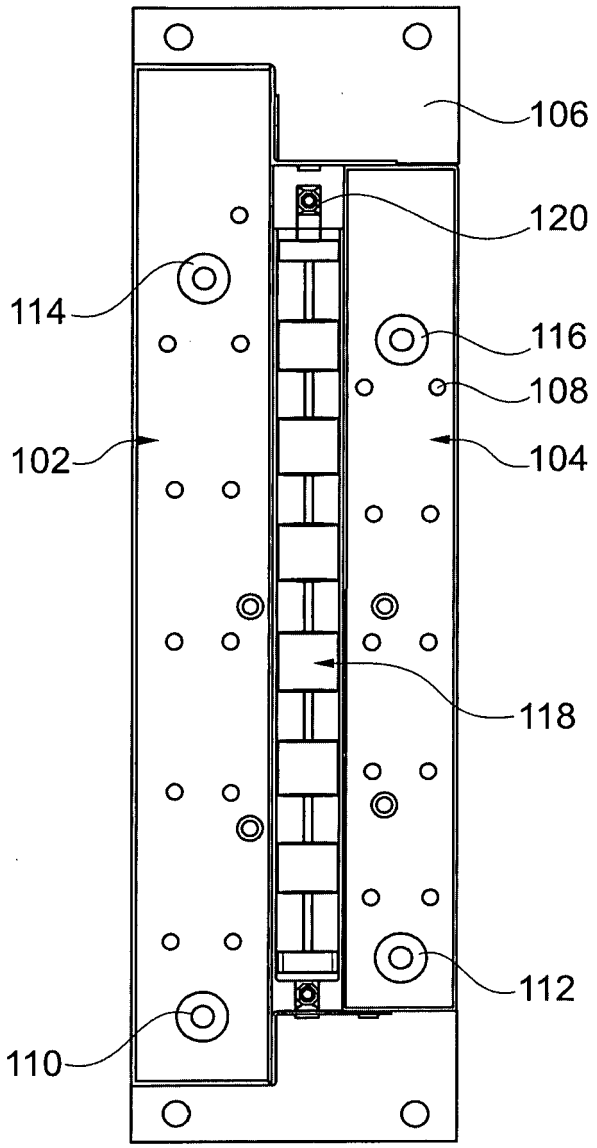


Fig. 8

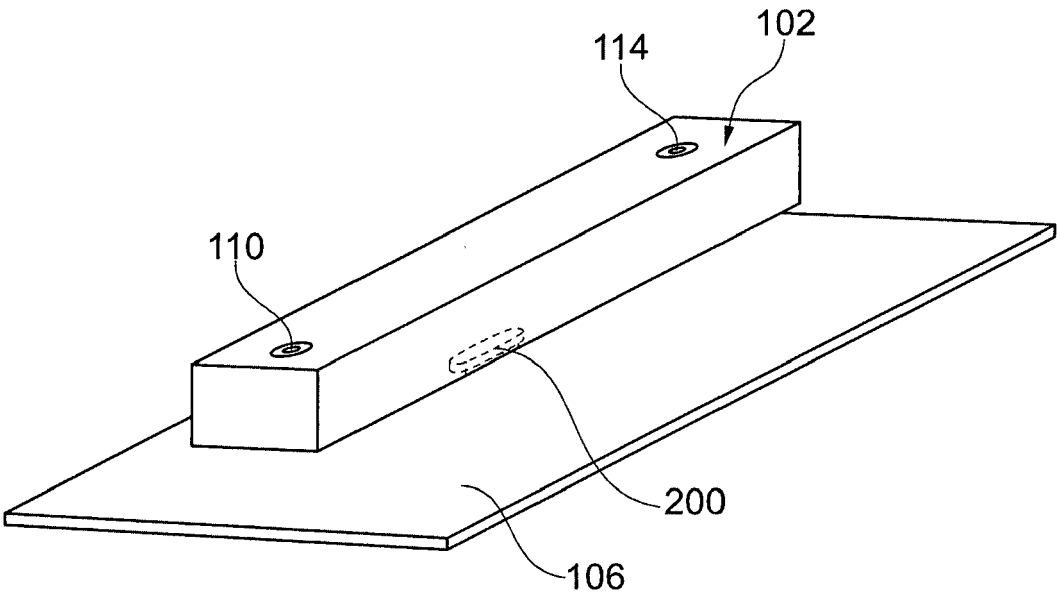


Fig. 9

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