(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/11711 A1

(51) International Patent Classification[7]: H01P 1/205

(21) International Application Number: PCT/IB00/01336

(22) International Filing Date: 3 August 2000 (03.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/147,678 6 August 1999 (06.08.1999) US
09/624,095 24 July 2000 (24.07.2000) US

(71) Applicant: UBE ELECTRONICS, LTD. [JP/JP]; 2023-2, Mugigawa, Okubun, Ohmine-Cho, Mine City, Yamaguchi Pref. 759-2214 (JP).

(71) Applicants and
(72) Inventors: KITAJIMA, Masahiko [JP/JP]; 5-10-71, Onda, Ube City, Yamaguchi Pref. 759-0207 (JP). FUJIYAMA, Yoshiaki [JP/JP]; 354, Aio Hutajima, Yamaguchi City 754-0839 (JP). NISHIMURA, Kosuke [JP/JP]; 2-3-1, Nishi-Kiwanamidai, Ube City, Yamaguchi Pref. 759-0207 (JP).

(74) Agent: YAMASHITA, Johei; Yamashita & Associates, Toranomon 40th Mori Bldg.,, 13-1, Toranomon 5-chome, Minato-ku, Tokyo 105-0001 (JP).

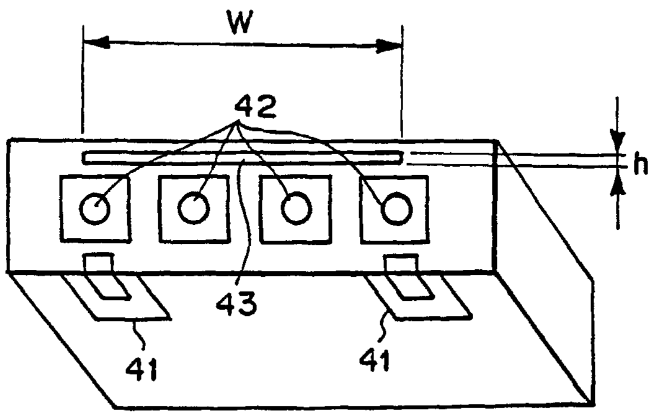
(81) Designated States *(national)*: BR, CN, FI, JP, KR.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DIELECTRIC FILTER WITH A TRANSMISSION LINE



(57) Abstract: A reduced size ceramic block filter has at least two holes extending through the filter from its top surface to its bottom surface and a transmission line printed on the top surface between the holes and the top surface edge of the filter that joins with a side wall running along the width of the filter. Conductive material covers substantially all of the bottom surface, the side wall surfaces and the inner surface of the holes. Trap holes are not needed as their function is replaced by the interaction of the transmission poles and the transmission line.

WO 01/11711 A1

DIELECTRIC FILTER WITH A TRANSMISSION LINE

CROSS REFERENCE TO PROVISIONAL APPLICATION

The present invention claims the benefit of U.S. Provisional Application No. 60/147,678, filed on August 6, 1999.

FIELD OF THE INVENTION

This invention relates to ceramic block filters with high performance in a small package. More specifically, the present invention relates to a new design for a high performance dielectric ceramic filter that is smaller than conventional filters with comparable performance specifications.

BACKGROUND OF THE INVENTION

A ceramic body with a coaxial hole bored through its length forms a resonator that resonates at a specific frequency determined by the length of the hole and the effective dielectric constant of the ceramic material. The holes are typically circular, or elliptical. Combining multiple resonators may form a dielectric ceramic filter. The holes in a filter must pass through the entire block, from the top surface to the bottom surface. This means that the depth of a hole is the exact same length as the axial length of a filter. The axial length of a filter is selected based on the desired frequency and specified dielectric constant of ceramic.

The ceramic block functions as a filter because the resonators are inductively coupled and/or capacitively coupled between every two adjacent resonators. These couplings are formed by the electrode pattern designed on the top surface of the ceramic block, plated with a conductive material such as silver or copper. More specifically and with reference to Figures 9A-D, a ceramic block 101 is shown with two holes 103 and 105. All surfaces, except for the front open face 107 through which the two holes 103 and 105 extend, are plated with silver. Due to the size of the holes, their proximity and the conductive coating, the two holes 103 and 105 are inductively and capacitively coupled to each other. However, block 101 will not perform as a filter because these couplings cancel each other out.

To form a filter, a pattern of conductive material is printed on face 107, as shown in Figure 9B. In this embodiment the patterns A and A\` enhance the capacitive coupling between holes 103 and 105. While the capacitive coupling is enhanced, the inductive coupling remains substantially unaffected. This is because inductive coupling is mostly a function of the hole diameter, shape and spacing between holes. These parameters are the same in Figures 9C and 9D.

The capacitive coupling can be regulated in Figure 9B by adjusting parameters L and G. By decreasing G or increasing L, the capacitive coupling is strengthened. The capacitive coupling can also be weakened such that the inductive coupling is stronger, by printing line M on open face 107. The simple line M in Figure 9C has a greater diminishing effect on the capacitive coupling of the block filter 101, than the broken line M\` of Figure 9D.

Ceramic filters are well known in the art and are generally described for example in U.S. Patent Nos. 4,742,562; and 4,692,726, both of which are hereby incorporated by reference as if fully set forth herein.

With respect to its performance, it is known in the art that the band pass characteristics of a dielectric ceramic filter are sharpened as the number of holes bored in the ceramic block are increased. The number of holes required depends on the desirable attenuation properties of the filter. Typically a simplex filter requires at least two holes while a duplexer (having a transmitter filter and a receiver filter) requires more than three holes. This is illustrated in Figure 1 where graph 10 represents the filter response with fewer holes than graphs 12 and 14. It is apparent that graph 14 which is the response of the filter with the most holes. is the sharpest of the three responses shown. Referring to Figure 2, it can be seen that the band pass characteristic of a particular dielectric ceramic filter is also sharpened with the use of trap holes bored into the ceramic block. Solid line graph 21 represents the response of a filter without a high end trap. Dashed line graph 23 represents the response of the same filter with a high end trap.

Trap holes. or traps as they are commonly referred to are resonators which resonate at a frequency different from the primary filter holes, commonly referred to simply as holes. They are designed to resonate at the undesirable frequencies. Thus. the holes transmit signals at the desirable frequencies while the traps remove signals at the undesirable frequencies. whether low end or high end. In this manner the characteristic of the filter is defined. i.e. high pass. low pass, or band pass.

The traps are spaced from holes a distance greater than the spacing between holes so as to avoid mutual interference between the holes and traps. As shown in Figure 3. whereas holes 31 are separated from each other a distance equal to D, a distance of 2D is placed between trap 33 and the hole nearest to trap 33. The precise distance being a design choice for achieving a specified performance. D Typically falls within a preferred range of 1 to 10mm. Traditionally, the traps will be spaced from 1.5D to 2D from the holes.

It should be clear, that the need for trap holes with their requisite spacing requirements in a filter adds a significant constraint to the degree to which the filter can be made smaller.

SUMMARY OF THE INVENTION

A ceramic block filter for a given performance includes at least two transmission poles and a transmission line printed on the top surface of the block filter. The transmission line is printed between the transmission poles and one of the long edges of the block filter. The interaction of the transmission line with the transmission poles results in a transmission zero. Transmission zero is the mathematical concept that describes the response characteristics of a filter, where a given filter decreases the frequency of an incoming signal to the filter and passes the signal of another frequency. With proper design of the geometry of the transmission lines, the resulting transmission zero can be made equivalent to one or more trap holes found in a conventional ceramic block filter. Accordingly, use of the transmission line in accordance with the present invention allows for the elimination of the trap holes of a conventional filter designed for the same performance, resulting in a smaller filter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the increased sharpness of the bandpass response of a dielectric ceramic filter as the number of holes in the filter increase.

Figure 2 illustrates the effectiveness of traps in removing high end frequencies.

Figure 3 is representative of the spacing between holes and hole and trap on a conventional ceramic block filter. Holes are represented by 33 while the trap is represented by 31.

Figure 4 depicts the dielectric ceramic block filter of the present invention with a transmission line printed on the top surface of the filter.

Figure 5 is the equivalent electrical circuit of the filter shown in Figure 4.

Figure 6 is a plot of three different filter responses: no trap; one trap; and no trap with a transmission line.

Figure 7 is a plot of two filter responses showing the improved performance of the filter of the present invention over a conventional filter without a trap.

Figure 8A depicts a conventional filter with a low end trap requiring a ceramic block with a relatively large width.

Figure 8B depicts one embodiment of the present invention without a low end trap and having a ceramic block with a relatively small width.

Figure 8C depicts another embodiment of the present invention without low end trap and having a ceramic block with a relatively small width.

Figure 9A illustrates the open face surface of a ceramic block plated with silver on all other surfaces.

Figure 9B illustrates the ceramic block of Figure 9A, but with a printed pattern on the open face surface.

Figure 9C illustrates the ceramic filter of figure 9B with a second printed pattern.

Figure 9D illustrates the ceramic filter of Figure 9C with a third printed pattern.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 4, the dielectric ceramic filter designed in accordance with the present invention has no low end trap. Rather the filter has four transmission poles 42, electrode pads 41 as in any conventional dielectric ceramic filter, and a transmission line 43 printed on the top surface, having width (w)and height (h).

Values for w = 3 – 15mm.

Values for h = 0.1 –2.0mm.

The transmission line 43, is located on a surface of the filter such that it is located between the edge of the transmission poles 42 and an edge of the filter. The distance between the edge of the transmission poles 42 to the transmission line 43 is 0.5 – 2.0 mm. The distance between the transmission line 43 and aforementioned filter edge, which the transmission line 43 is placed between that and the edge of the transmission poles is 0.5 – 2.0 mm.

Values for the transmission pole's 42 holes diameter are 0.3 – 2.0 mm

The distance between transmission pole 42 holes is/are 0.5 – 5.0 mm.

The manufacture of block filters is known in the art, including the process of laying the conductive material on the dielectric. Filters made in accordance with the present invention may be simplex (a single filter) or duplex (the combination of two filters such as a transmitter filter and a receiver filter). As stated above, the usual conductive materials of choice are copper or silver. The conductive material generally covers substantially all of the bottom and side walls of the ceramic block. This is accomplished by one of several known methods. These include dipping, spraying or printing a copper or silver paste onto the dielectric and firing the coated dielectric. Other methods include electrolytic plating or electroless plating, also processes well known in the art. As with other dielectric filters the choice of dielectric is one of design. In one advantageous embodiment of the present invention, the dielectric is ceramic and has an effective dielectric constant between 20 and 150.

The equivalent electrical circuit for the filter of Figure 4 is shown in Figure 5. From Figure 5 it can be seen that the interaction between transmission line 43 and the four transmission poles 42 result in four capacitors 45 a-d. Electrode pads 41 are also described in Figure 5. The transmission line 43 of Figure 4 is represented as inductor 44 characteristic on the circuit diagram of Figure 5. The interaction between the inductor 44 characteristic of transmission line 43 and the four capacitors 45 a-d result in a transmission zero. Traps are conventionally used to create a transmission zero, however, they are no longer necessary where a transmission line 43 is used as it is in the present invention. Thus, the elimination of traps allows the present invention to be physically smaller in size than conventional filters with trap holes and similar performance capabilities. (See Figure 6). Further, the present invention also results in an improved performance over conventional filters without trap holes. (See Figure 6 and 7).

The transmission line 43 is preferably formed with a silver paste on the top surface of the filter and its frequency response is defined by $f = 1/(LC)^{1/2}$ where L is the inductance of the transmission line 43 and C is the combined capacitance of the capacitors 45 a-d.

Referring to Figure 6, three graphs are plotted showing the response of three different filters designed to provide similar performance. The filter response graph 63 is clearly in need of attenuation, as the undesirable low end frequencies have a significant presence at the output of the filter. Graph 63 is the response of a four transmission pole filter without any traps. In contrast, the filter response is considerably improved for graph 62. Graph 62 is the response of a filter with the same four transmission poles and one trap.

Finally, graph 61 (solid line curve) represents the response of a filter in accordance with the present invention in which the same four transmission poles are present, but without any traps. However, a transmission line as described above was printed on the top surface of the filter. Clearly, the response of the filter of the present invention is equivalent to that of the filter with the trap. Yet, the filter with the transmission line has a significantly smaller package, as shown below.

Similarly, the enhanced performance that is realized with the filter of the present invention, as compared with a conventional filter without a trap, can be seen from Figure 7. Graph 71 (solid line graph) depicts the response of the filter of the present invention, while graph 72 depicts the response of a conventional filter without any traps.

By replacing the low end trap with a transmission line the size of the filter is reduced considerably. This is readily apparent by comparing the top plan views of the filters shown in Figures 8A and 8B. In Figure 8A a conventional filter with a low end trap 81 is shown. This filter is clearly wider than the filter shown in Figure 8B which has no low end trap, only transmission line 82, which has no bearing on the width of the filter. The parameters in determining the design of a transmission line include width of the transmission line, height of the transmission line, and distance of the transmission line from the edge of the filter and the distance of the transmission lines between it and the transmission pole holes.

The foregoing merely illustrates the principles of the present invention. Those skilled in the art will be able to devise various modifications, which although not explicitly described or shown herein, embody the principles of the invention and are thus within its spirit and scope.

WHAT IS CLAIMED IS

1. A filter, comprising:

a block of dielectric material having a top surface, a bottom surface, two opposing side walls connecting said top surface to said bottom surface along the width of said block of dielectric material and two side walls connecting said top surface to said bottom surface along the height of said block;

a plurality of holes extending through said block from said top surface to said bottom surface, each of said holes having the characteristic of a transmission pole;

conductive material covering substantially all of the bottom surface, said side wall surfaces and the inner surface of said holes; and

at least one transmission line printed on said top surface of said block between said plurality of holes and an edge of said block of dielectric material formed by said top surface and one of said side walls along the width of said block of dielectric material.

2. The filter of claim 1 wherein said plurality of holes comprise at least three transmission poles.

3. The filter of claim 1 wherein said transmission line has a height (h) of 0.1 –2.00 mm and a width (w) of 3 – 15 mm.

4. The filter of claim 2 wherein said transmission line has a height (h) of 0.1 –2.00 mm and a width (w) of 3 – 15 mm.

5. The filter of claim 1 wherein said transmission line is located a distance of 0.5 – 2.00 mm from the edge of said plurality of holes and a distance of 0.5 – 2.00 mm of said edge of said block of dielectric material, so that said transmission line is between said

plurality of holes and said edge of said block.

6. The filter of claim 2 wherein said transmission line is a distance of 0.5 –2.00 mm from the edge of said plurality of holes and a distance of 0.5 – 2.00 mm of said edge of said block of dielectric material, so that said transmission line is between said plurality of holes and said edge of said block.

7. The filter of claim 3 wherein said transmission line is a distance of 0.5 –2.00 mm from the edge of said plurality of holes and a distance of 0.5 – 2.00 mm of said edge of said block of dielectric material, so that said transmission line is between said plurality of holes and said edge of said block.

8. The filter of claim 4 wherein said transmission line is a distance of 0.5 –2.00 mm from the edge of said plurality of holes and a distance of 0.5 – 2.00 mm of said edge of said block of dielectric material, so that said transmission line is between said plurality of holes and said edge of said block.

9. The filter of claim 1 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

10. The filter of claim 2 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

11. The filter of claim 3 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

12. The filter of claim 4 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

13. The filter of claim 5 wherein the diameter of said holes is 0.3 –2.0 mm and the

distance between said holes is 0.5 –5.0 mm.

14. The filter of claim 6 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

15. The filter of claim 7 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

16. The filter of claim 8 wherein the diameter of said holes is 0.3 –2.0 mm and the distance between said holes is 0.5 –5.0 mm.

FIG.1

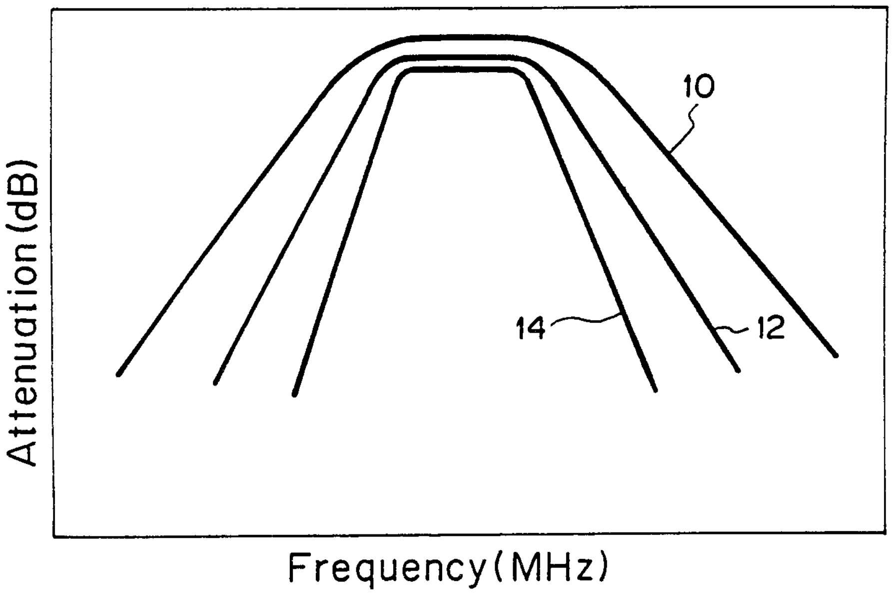


FIG.2

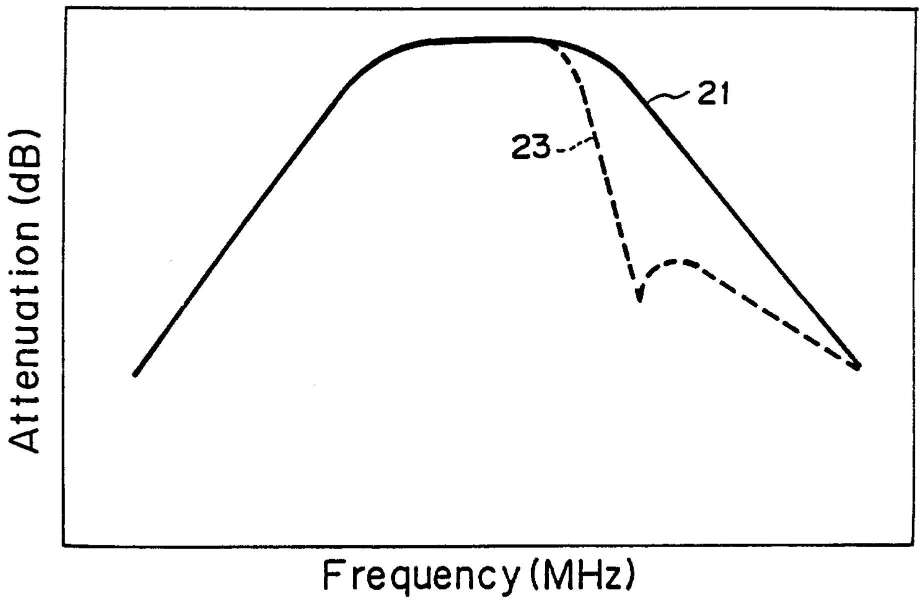


FIG.3

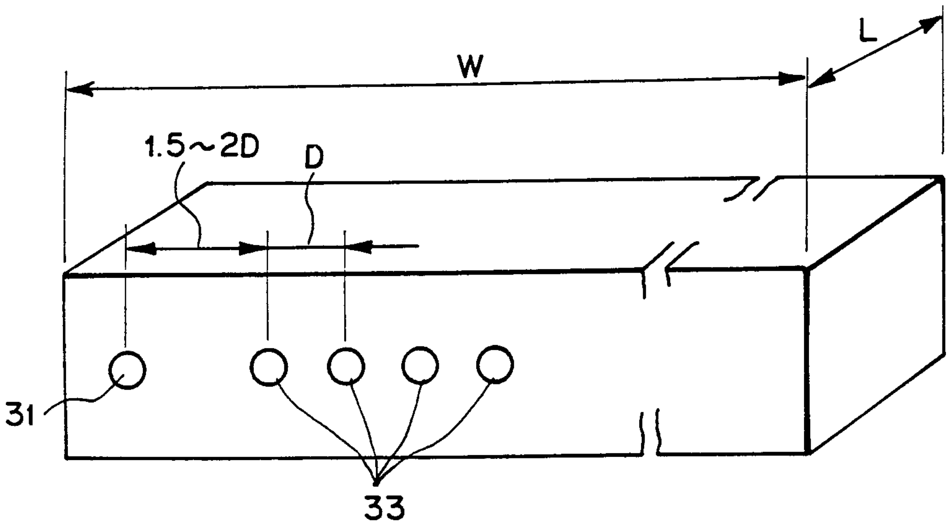


FIG.4

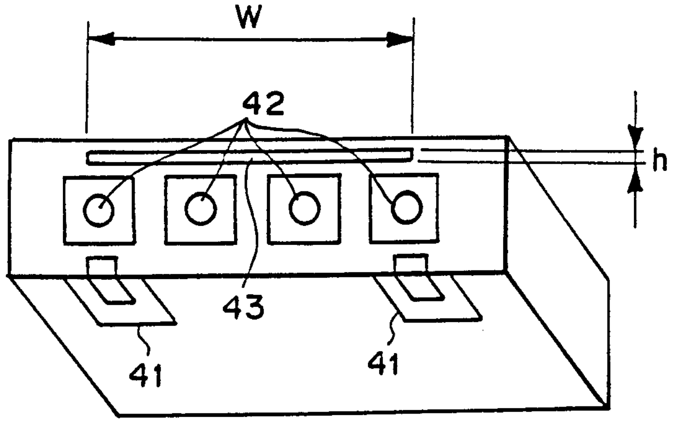


FIG.5

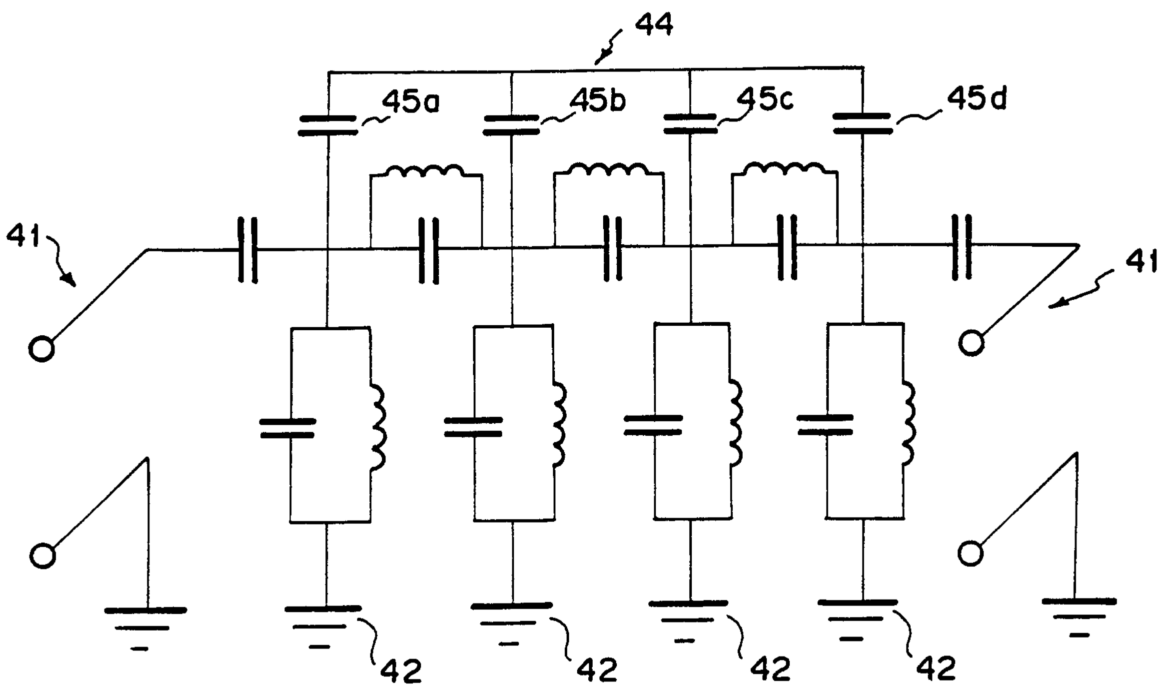


FIG.6

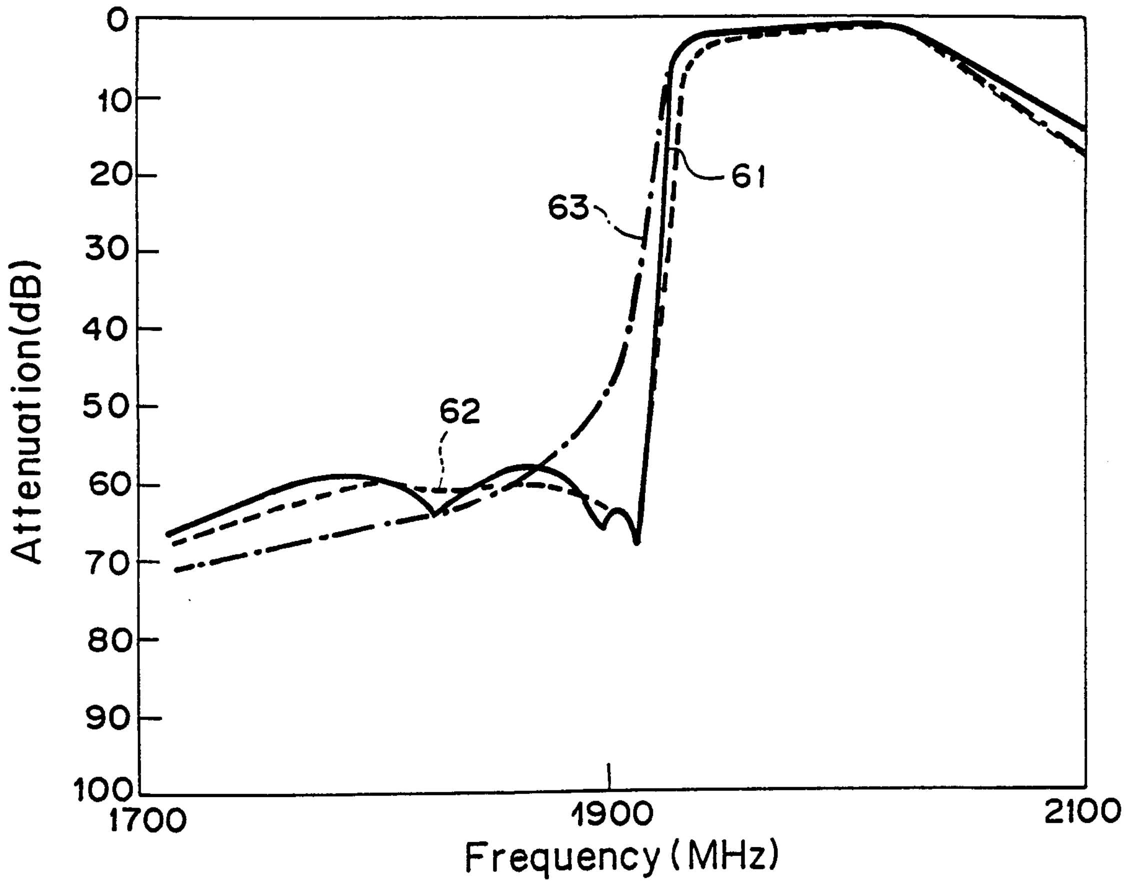

0
10
20
30
40
50
60
70
80
90
100
Attenuation(dB)
61
62
63
1700
1900
2100
Frequency (MHz)

FIG.7

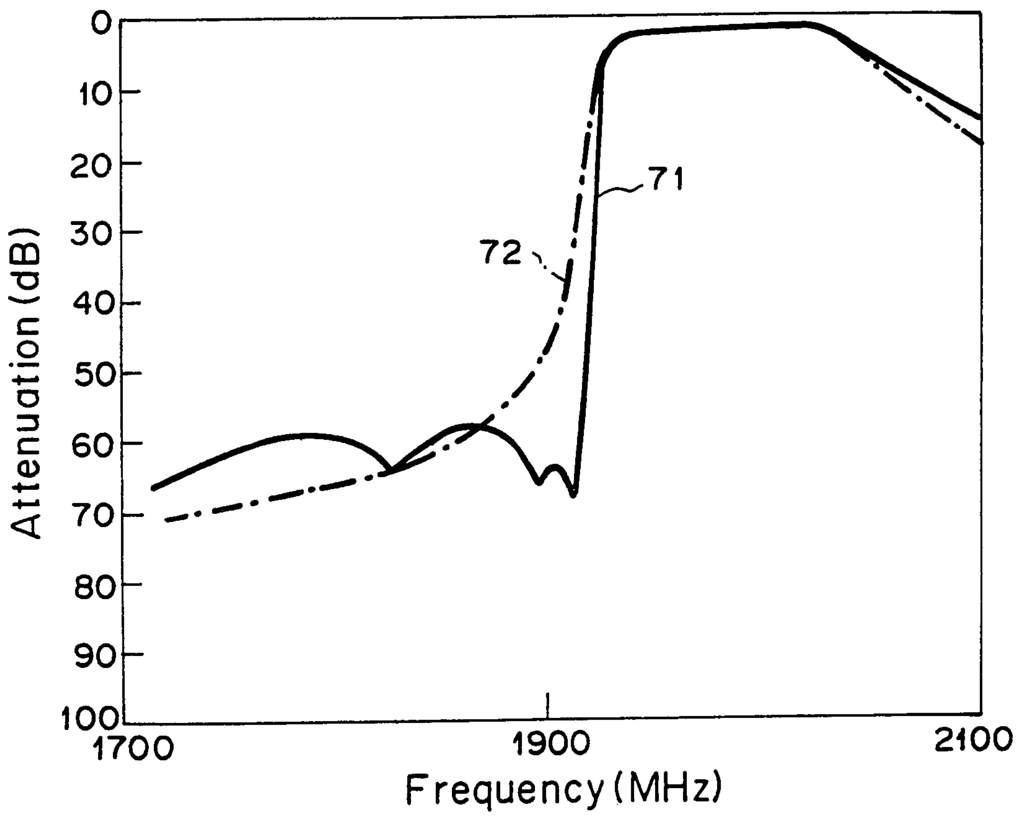

0
10
20
30
40
50
60
70
80
90
100
Attenuation (dB)
71
72
1700
1900
2100
Frequency (MHz)

FIG.8A

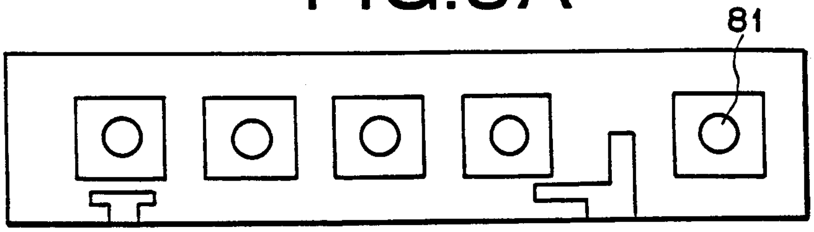


FIG.8B

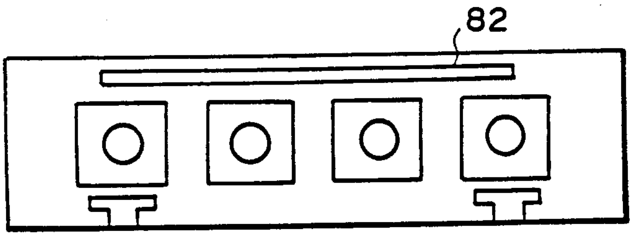


FIG.8C

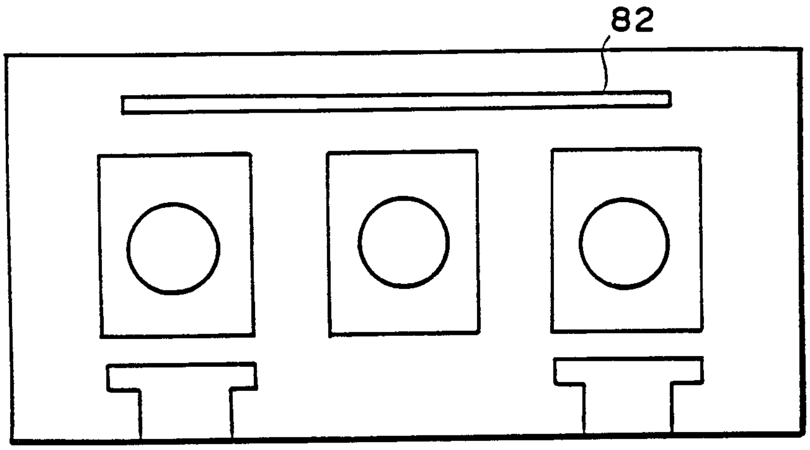


FIG.9A

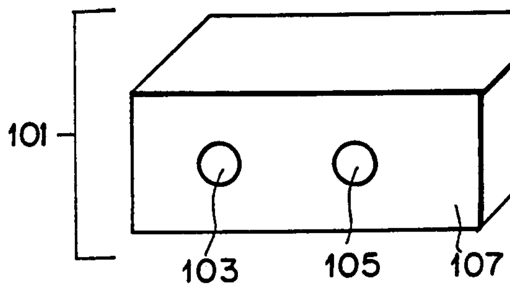


FIG.9B

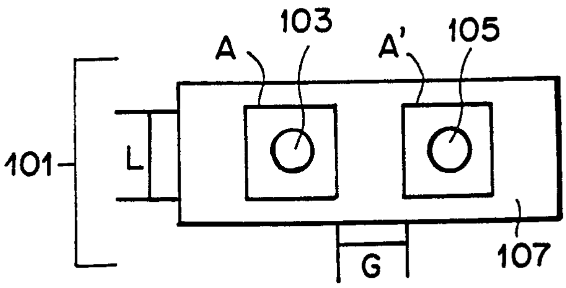


FIG.9C

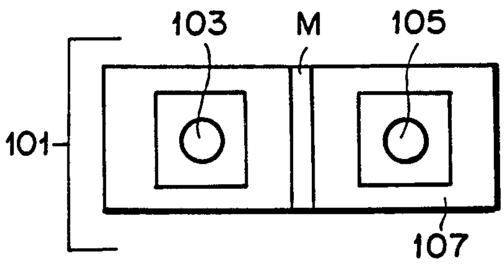
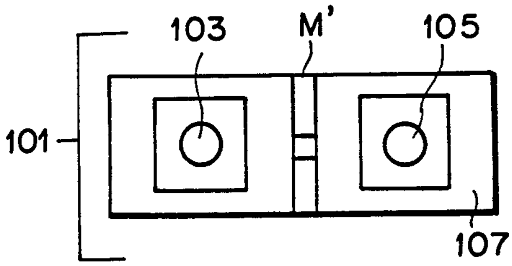


FIG.9D



INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 00/01336

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P1/205

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 740 765 A (ISHIKAWA ET AL.) 26 April 1988 (1988-04-26) column 2, line 58 -column 3, line 48; figure 1	1,2
Y		9,10

Y	US 5 436 602 A (MCVEETY ET AL.) 25 July 1995 (1995-07-25) column 5, line 56 - line 61 column 6, line 7 - line 11; figure 1	9,10
A		3-8, 11-16

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 January 2001	16. 01. 2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Den Otter, A

1

International Application No
PCT/IB 00/01336

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 16, no. 567 (E-1296), 8 December 1992 (1992-12-08) -& JP 04 220001 A (MURATA MFG CO LTD), 11 August 1992 (1992-08-11) abstract; figures 22,23 -----	1,2

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IB 00/01336

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4740765 A	26-04-1988	JP 62077703 A	09-04-1987
		JP 62157402 A	13-07-1987
US 5436602 A	25-07-1995	US 5537085 A	16-07-1996
JP 04220001 A	11-08-1992	NONE	