(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 882 034 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
10.06.2015 Bulletin 2015/24

(21) Application number: **13290304.8**

(22) Date of filing: **09.12.2013**

(51) Int Cl.:
H01P 1/208 *(2006.01)* ***H01P 1/215*** *(2006.01)*
H01P 7/10 *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **ALCATEL LUCENT**
92100 Boulogne-Billancourt (FR)

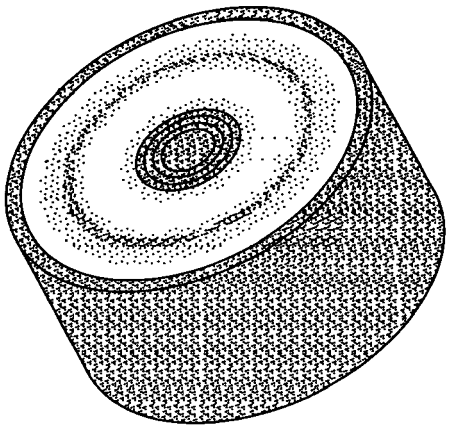
(72) Inventors:
- **Rulikowski, Pawel K.**
Blanchardstown, Dublin 15 (IE)
- **Bulja, Senad**
Blanchardstown, Dublin 15 (IE)

(74) Representative: **Sarup, David Alexander**
Alcatel-Lucent Telecom Ltd
Intellectual Property Business Group
Christchurch Way
Greenwich
London SE10 0AG (GB)

(54) **A radio-frequency or microwave resonator, a filter, and a method of filtering**

(57) A radio-frequency or microwave resonator is provided comprising a dielectric ceramic core 14 having a ferromagnetic ceramic covering 16. The covering in use provides a magnetic wall boundary to radio frequency signals inside the resonator.

FIG. 3
(PRIOR ART)



EP 2 882 034 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

[0001] The present invention relates to telecommunications, in particular to resonators for possible use in radio-frequency or microwave filtering.

Description of the Related Art

[0002] Filters are a key component of many radio-frequency (RF) and microwave-frequency systems such as for example cellular telecommunications base stations, point-to-point radio transceivers, and radar systems. The type of filter chosen depends on the particular application, but there are certain common desirable characteristics for filters. For example, the insertion loss in the pass-band of the filter should be as low as possible, and the attenuation in the stop-band should be as high as possible. Furthermore, in some applications the frequency separation between the pass-band and stop-band needs to be very small, requiring a filter of high order. This frequency range is known as the guard-band.

[0003] A challenging aspect of filter design is how to miniaturise the filter whilst maintaining electrical performance as compared to a similar but larger filter structure.

[0004] One of the main parameters determining a filter's selectivity in terms of frequency, and insertion loss, is the so-called quality factor ("Q factor") of the elements that make up the filter. The Q factor is defined as the ratio of energy stored in the filter element to the time-averaged power loss.

[0005] In filters designed for low RF frequencies, lumped elements are used. Lumped elements have a Q factor in an approximate range of 60 to 100. On the other hand, cavity type resonators that can be used to construct filters have a Q factor which can be as high as several 1000s.

[0006] Although some miniaturisation of lumped element filters is possible, their low Q factors prohibit their use in highly demanding applications where high frequency rejection or selectivity is required. On the other hand, cavity resonators offer sufficiently high Q factors but their large sizes prevent their use in many applications.

[0007] The problem of miniaturising filters is known to be particularly pressing in the field of small cell base stations, as it has been realised that the footprint of a small cell base stations should be minimal. Furthermore, a known trend in base stations is a shift from a single frequency band capability to a multiband capability whilst seeking to maintain the same physical footprint and avoid detriment to system performance.

[0008] Several known solutions exist. For relatively low powers, ceramic monoblock filters are known with external metallisation. They offer significant size reduction but because of their relatively low Q factor of some 100s (typically 500 to 700) are unsuitable for many applications. Furthermore, their small size prevents their use in high power applications due to relatively high insertion losses and limited power handling capabilities.

[0009] Another known type of filters are those made up from ceramic resonators. These offer significant size reductions but are able to handle much higher powers than monoblock filters.

Summary

[0010] The inventor realised that it was known to use high permeability materials in resonator design to reduce the size of resonator in proportion to the square root of real relative permittivity (ε_r) times real relative permeability (μ_r), denoted $\sqrt{\varepsilon_r \mu_r}$.

[0011] The inventor also realised that known ceramic filters are built from ceramic resonators in which the ceramic material is dielectric having a real relative permeability (μ_r) of about 1, but a real relative permittivity of several tens, usually in range of 30 - 80.

[0012] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0013] An example of the present invention is a radio-frequency or microwave resonator comprising a dielectric ceramic core having a ferromagnetic ceramic covering, the covering in use providing a magnetic wall boundary to electromagnetic signals inside the resonator.

[0014] The inventor found a way to produce a radio-frequency resonator having improved properties by including ferromagnetic ceramic covering. For example, a more even energy distribution within the core is provided.

[0015] Preferred embodiments provide a magnetic wall boundary dielectric resonator.

[0016] Preferred embodiments are a combination of both dielectric and ferromagnetic ceramic parts in an arrangement that allows the size of the dielectric part to be reduced, as compared to a comparable filter in which the ferromagnetic part is absent, for the same filtering frequency and without a significant increase in energy losses in the resonator.

[0017] In preferred embodiments, not only does the dielectric ceramic part confine electromagnetic energy due to the high contrast between the dielectric ceramic part's permittivity and surrounding material(s), but also the ferromagnetic ceramic covering acts to aid that energy confinement as it introduces a high contrast between the permeability of the dielectric ceramic and the ferromagnetic ceramic covering.

[0018] It can be considered that the ferromagnetic ceramic covering enhances the magnetic wall boundary at the surface of the dielectric ceramic bringing it closer to perfect magnetic boundary conditions.

[0019] Preferred embodiments allow a significant reduction in resonator size, and hence filter size, due to introducing a material of high relative permeability in addition to a material of high relative permittivity.

[0020] Preferred embodiments provide reduced size filters comprising reduced size resonators. Preferred embodiments allow miniaturisation of ceramic resonators that may be cavity resonators, for example at least partially filling cavities within a metallic outer casing.

[0021] Preferred embodiments may be smaller sized, with better RF power handling and thermal properties than a known alternative.

[0022] Preferred embodiments operate in the radio-frequency or microwave frequency bands.

Brief Description of the Drawings

[0023] An embodiment of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is a diagram illustrating a known cylindrical radio-frequency ceramic resonator within a metal casing (PRIOR ART),
Figure 2 is a diagram illustrating the magnitude of the electric field across the diameter of the resonator shown in Figure 1 (PRIOR ART),
Figure 3 is a perspective illustration of how magnitude of this electric field varies in the resonator shown in Figure 1 (PRIOR ART),
Figure 4 is a diagram illustrating a cylindrical radio-frequency ceramic resonator according to an embodiment of the present invention within a metal casing, and
Figure 5 is a diagram illustrating the magnitude of the electric field across the diameter of the resonator shown in Figure 4,
Figure 6 is a perspective illustration of how the magnitude of this electric field varies in the resonator shown in Figure 4,
Figure 7 is a perspective view of a filter including resonators as shown in Figure 4,
Figure 8 is a cross-sectional view along the line A-A of the filter shown in Figure 7, and
Figure 9 is a perspective cross-sectional view of the filter shown in Figures 7 and 8.

Detailed Description

[0024] The inventors considered a known ceramic resonator 2 as shown in Figure 1. As shown in Figure 1, this known resonator 2 consists of a cylindrical core 4 of dielectric ceramic material fitting tightly within a metal casing 8. The shape of the core 4 can be considered a puck 6. In this example, the real relative permittivity of the core 4 is 38, the height is 12mm and the diameter is 25mm. The first (lowest radio-frequency) resonating mode is TM_{010}.

[0025] The inventors realised that an improved field distribution was possible.

[0026] As shown in Figure 4, the inventors devised a resonator 12 consisting of a cylindrical core 14 of dielectric ceramic material, surrounded by a tightly fitting thin cylindrical ring 16 of ceramic ferromagnetic material, also known as ferrite. In this example the ceramic material is Ceramic DR-45 from TCI Ceramics Inc, and the ferromagnetic material is garnet NG-1850 from TCI Ceramics Inc. This assembly of core 14 and ferrite ring 16 fits into a tightly-fitting metal casing 18. The core 14 and ferrite ring 16 can be considered together as a puck 20. In this example, the real relative permittivity of the core 14 is 38, the height is 12mm and the diameter is 25mm. The first (lowest radio-frequency) resonating mode is TM_{010}. The ferrite ring 16 is made of ferrite material having a high relative magnetic permeability (μ_r) of 100. In this example the thickness of the ferrite 16 is 1 mm.

[0027] The inventors realised that ceramic ferromagnetic material (ferrite materials) possess an anisotropic real relative permittivity of up to 1000s, but are significantly more lossy, in other words have a significantly higher imaginary relative permittivity component, than dielectric ceramic materials, so their volumetric contribution to the resonator should be sufficient to be effective, but kept to a minimum.

Comparison of the two resonators

[0028] Comparison of Figure 5 with Figure 2, and Figure 6 with Figure 3, reveal that the electric field strength (E-Field) distributions are significantly different. More specifically, the resonator 2 of Figure 1 (PRIOR ART) shows a highly concentrated field in the centre of the puck 6 with the magnitude of the electric field steadily decaying towards the outer edge, which acts as an electric wall, where the field becomes zero. On the other hand, the resonator 12 of Figure 4 which includes the puck 20 having the ceramic core 14 and ferrite ring 16 shows a much more evenly distributed electric field through the volume of the puck 20 with a clearly defined field inside the ferrite ring 16 that rapidly decays as a function of distance towards the outer edge where the field becomes zero.

[0029] In the known example shown in Figures 1 (PRIOR ART) to 3 (PRIOR ART), the energy distribution is less uniform, hence the effective electrical size of the resonator is smaller, and so the resonant frequency is higher (1.479 GHz in this example).

[0030] Conversely, in the example shown in Figures 4 to 6 the energy distribution is much more uniform, hence the effective electrical size is larger, and so the resonant frequency is lower (0.311 GHz in this example).

[0031] In the example shown in Figure 4, as the field is distributed much more evenly, there is no region of relatively high electric field; in other words the electric field "hotspot", which occurs in the known resonator shown in Figure 1 (PRIOR ART), is avoided. This advantageously allows for higher power handling than in the known approach.

[0032] In the known approach, as ceramics are poor heat conductors, the thermal stresses induced by the electric field "hotspot" can result in catastrophic structural failure. Furthermore uneven heat distribution tends to degrade electrical performance as different areas of the resonator are more likely to be at different temperatures resulting in varying thermal expansions and variations in permittivity due to temperature variations. The example shown in Figure 4 avoids these disadvantages.

Example Filter

[0033] An example filter 22 is shown in Figures 7 to 9, and includes two resonators 12 as described above in relation to Figures 4 to 6.

[0034] As shown in Figure 7 to 9, the filter 22 has a metal casing 24 within which is a cavity 26. The filter 22 is a two pole filter in that two resonators 12 are provided. The resonators 12 are coupled via an opening 28 known as an iris 28 between internal walls 30 in the cavity 26. The size of the opening 28 dictates the level of coupling between the two resonators 12.

[0035] The resonators 12 are both cylindrical and of a dielectric material of high permittivity, and are each sleeved in the respective ferrite ring 16 so as to provide a respective puck 20. The top (not shown) and bottom (not shown) of the puck 20 contact the respective top (not shown) and bottom 32 of the cavity 26. The cavity 26 is otherwise substantially air-filled.

[0036] The filter 22 includes a metallic end launch probe 34 near the first resonator 12' used for signal input. The distance between the probe and the resonator, and the length of the probe, dictate the amount of coupling and the loaded quality factor of the resonator. A similar metallic end probe 36 is provided near the second resonator 12" used for signal output.

[0037] As mentioned above each resonator 12 consists of a high permittivity dielectric core 12 covered at its sides by a ferromagnetic ring 16. The diameter of the resonator dictates the resonant frequency of the resonator 12 and effectively the centre frequency of the filter 22.

Some Alternative Examples

[0038] The above mentioned example resonator described with reference to Figure 4 to 6 is cylindrical, being in the shape of a puck 20. Other shapes are possible. For example, the resonator can be in the shape of a cylindrical puck or post, a puck or post of rectangular- or square- cross section, another regular shape, or any shape. Regular shapes are easier to machine. The ferrite material can be in the form of a sleeve that tightly fits the resonator or be a layer deposited on the dielectric ceramic material core.

[0039] In the example described with reference to Figures 4 to 6, the resonator is within a metal casing. The metal casing may be a tight-fitting to the resonator or not, for example the resonator can be used within a cavity in a cavity filter, for example a comb-line filter in which the resonator is substantially surrounded by air or some other material, for example a dielectric powder.

[0040] The present invention may be embodied in other specific forms without departing from its essential characteristics. For example, other dielectric and ferromagnetic materials may be used. These materials are available from various suppliers including TCI Ceramics Inc, Murata and Kyocera. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. A radio-frequency or microwave resonator, the resonator comprising a dielectric ceramic core having a ferromagnetic ceramic covering.

2. A radio-frequency or microwave resonator according to claim 1, in which the covering in use provides a magnetic wall boundary to electromagnetic signals inside the resonator.

3. A radio-frequency or microwave resonator according to claim 1 or claim 2, in which the covering has a relative permittivity lower than the relative permittivity of the core.

4. A radio-frequency or microwave resonator according to any preceding claim, in which the core is of a simple shape having sides and the covering covers said sides.

5. A radio-frequency or microwave resonator according to any preceding claim, in which the core is cylindrical and the covering is a tubular sleeve or ring.

6. A radio-frequency or microwave resonator according to claim 5, in which the core is a puck or post.

7. A radio-frequency or microwave resonator according to any preceding claim, in which the core is of rectangular cross-section and the covering is a sleeve of rectangular cross section.

8. A radio-frequency or microwave resonator according to claim 7, in which the core is a puck, post or a cuboid.

9. A radio-frequency or microwave resonator according to any preceding claim, in which the covering has a thickness thick enough to provide a high contrast in relative permeability with the core and thin enough to avoid large energy losses in the covering.

10. A radio-frequency or microwave resonator according to any preceding claim, in which the ferromagnetic ceramic has a relative permittivity of about 1.

11. A radio-frequency or microwave resonator according to any preceding claim, in which the ferromagnetic ceramic has a relative permeability in the order of tens to in the order of thousands.

12. A radio-frequency or microwave resonator according to any preceding claim, in which the dielectric ceramic has a relative permittivity in the range 30 to 300.

13. A radio-frequency or microwave radio-frequency resonator according to any preceding claim, further comprising a metal casing for electromagnetic shielding.

14. A filter comprising at least one radio-frequency or microwave resonator according to any preceding claim and a metal housing within which each resonator resides.

15. A method of filtering comprising passing an input signal through a filter comprising a radio-frequency or microwave resonator according to any of claims 1 to 13, so as to provide a filtered output signal.

FIG. 1
(PRIOR ART)

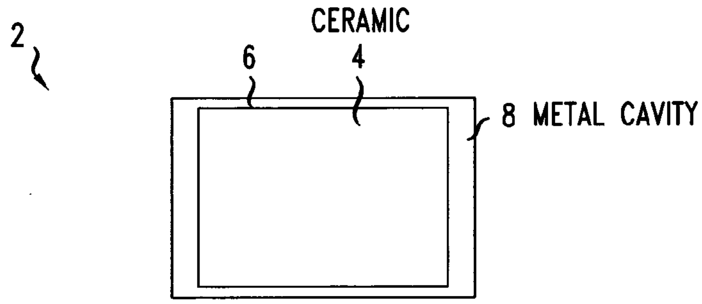


FIG. 2
(PRIOR ART)

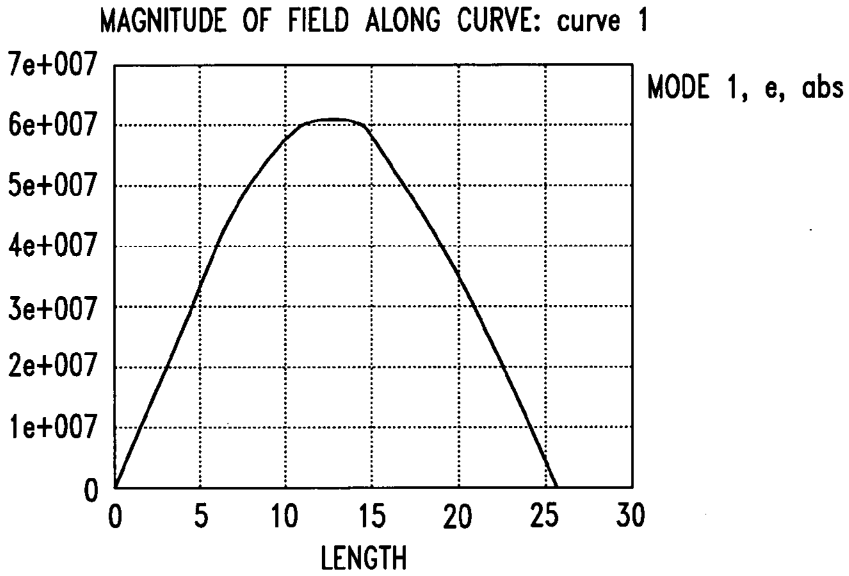


FIG. 3
(PRIOR ART)

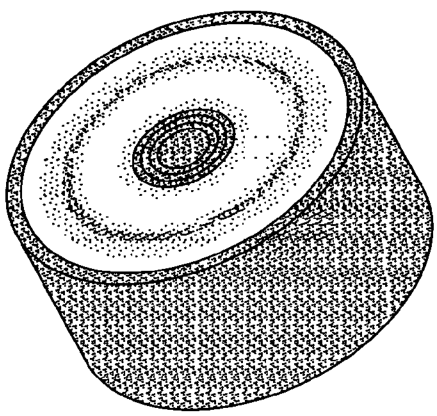


FIG. 4

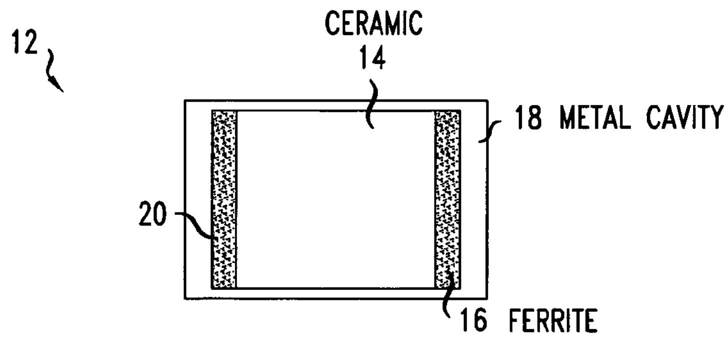


FIG. 5

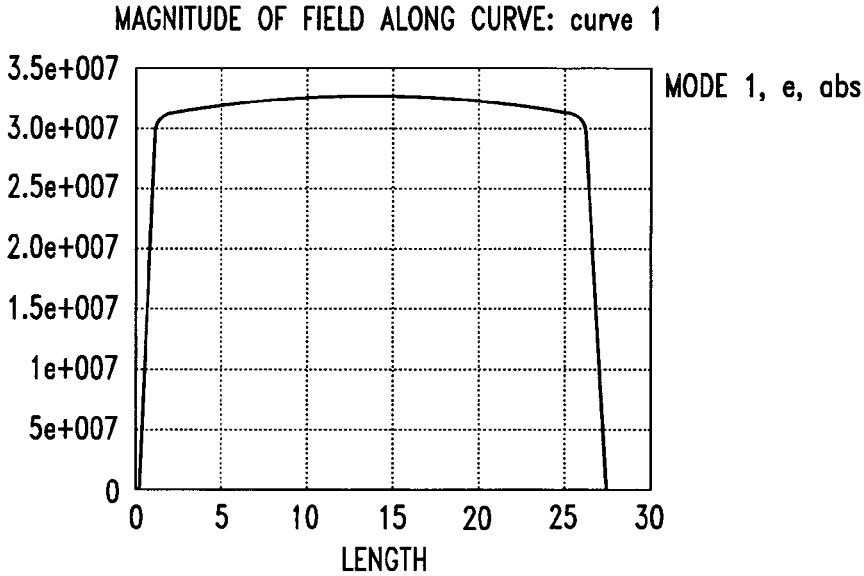


FIG. 6

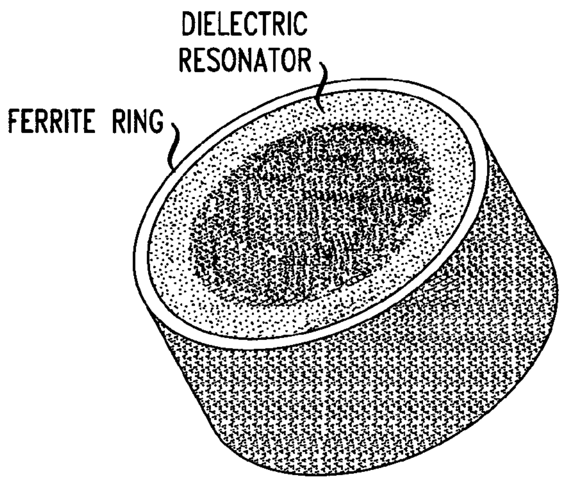


FIG. 7

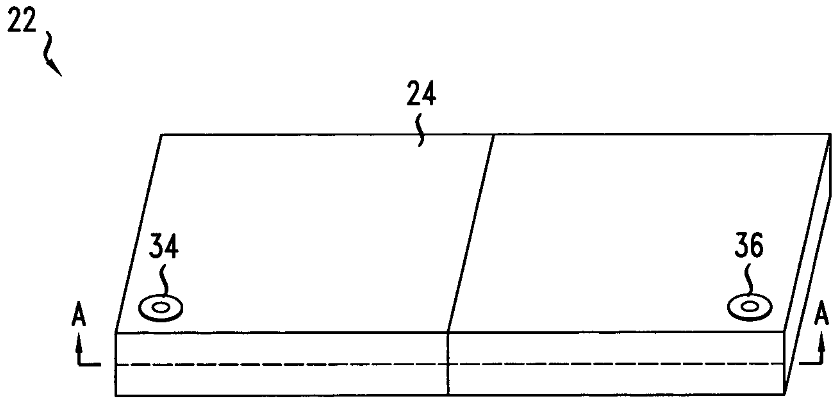
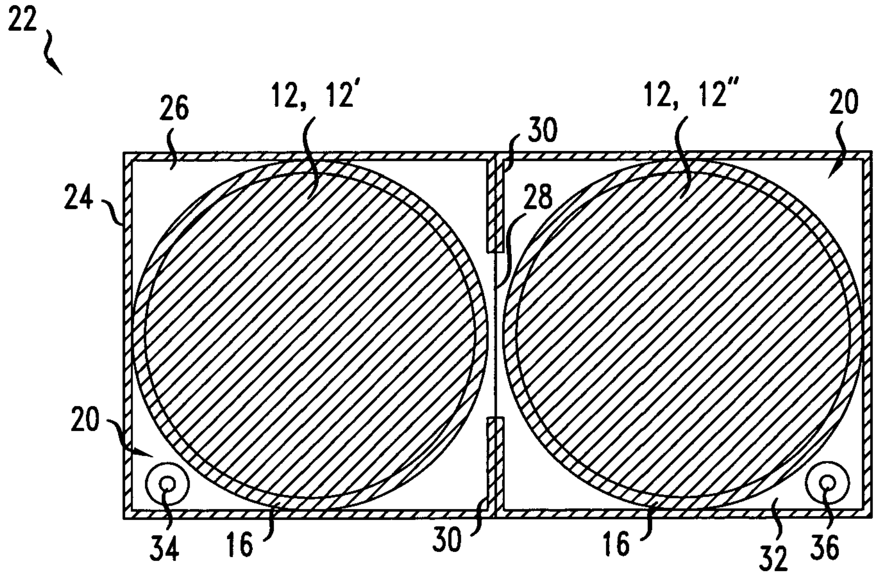


FIG. 8



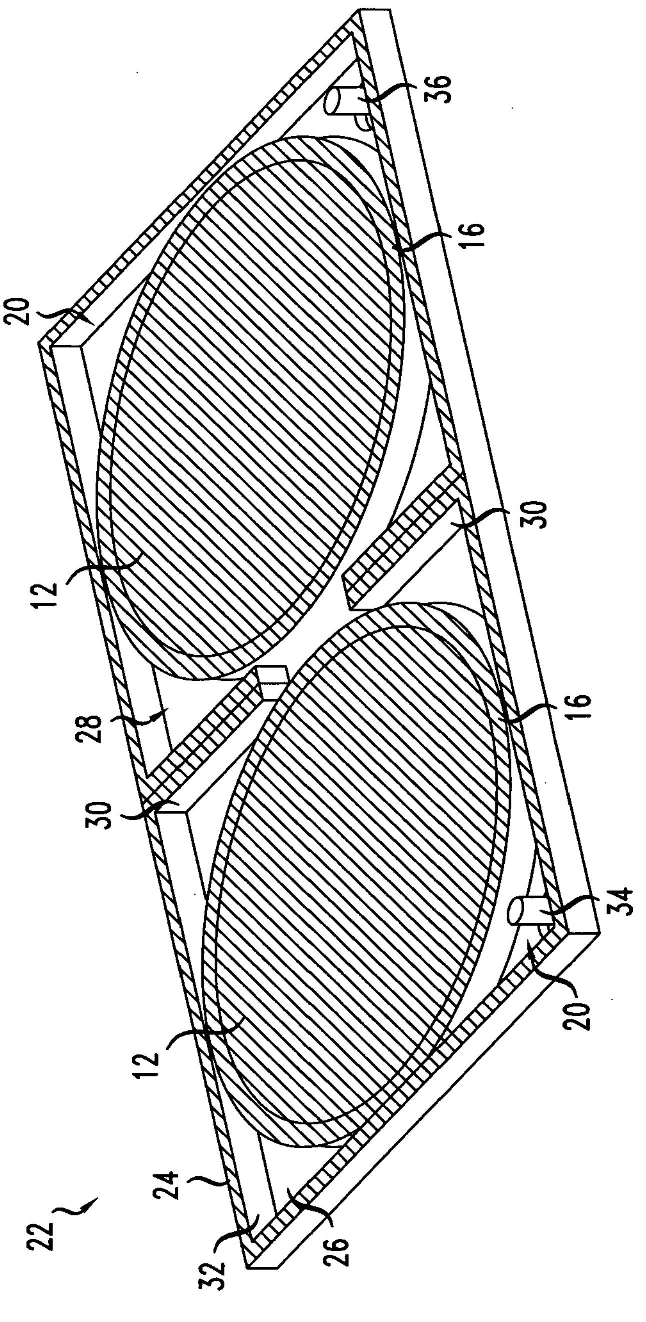


FIG. 9

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 13 29 0304

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 4 122 418 A (NAGAO TSUKASA) 24 October 1978 (1978-10-24) * figures 1a,1b * * column 2, line 62 - column 3, line 40 * * claim 7 * * column 20, lines 13-15 * -----	1-11,15	INV. H01P1/208 H01P1/215 H01P7/10
X	FR 2 521 786 A2 (THOMSON CSF [FR]) 19 August 1983 (1983-08-19) * figure 1 * * page 2, line 10 - page 3, line 3 * * page 1, lines 1-3 * -----	1,3, 12-15	
A	US 2001/045872 A1 (MIURA TARO [JP] ET AL) 29 November 2001 (2001-11-29) * abstract; figures 5,12 * * paragraphs [0056] - [0064] * * paragraphs [0101] - [0105] * -----	1-15	
A	US 5 469 128 A (KAWANISHI UMEO [JP] ET AL) 21 November 1995 (1995-11-21) * abstract; figures 39a-g * * column 21, lines 24-65 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC) H01P
A	GB 2 380 069 A (SOUTH BANK UNIV ENTPR LTD [GB]) 26 March 2003 (2003-03-26) * figure 1 * * page 1, line 25 - page 2, line 6 * * page 3, lines 3-23 * -----	1-15	

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	22 September 2014	Unterberger, Michael

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 29 0304

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-09-2014

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 4122418	A	24-10-1978	NONE	
FR 2521786	A2	19-08-1983	NONE	
US 2001045872	A1	29-11-2001	GB 2360877 A	03-10-2001
			JP 3494093 B2	03-02-2004
			JP 2001102813 A	13-04-2001
			US 2001045872 A1	29-11-2001
			WO 0126176 A1	12-04-2001
US 5469128	A	21-11-1995	NONE	
GB 2380069	A	26-03-2003	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82