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

(11) EP 2 432 070 B9

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Bibliography INID code(s) 74
Claims EN 9, 11

(48) Corrigendum issued on:
29.07.2015 Bulletin 2015/31

(45) Date of publication and mention of the grant of the patent:
13.02.2013 Bulletin 2013/07

(21) Application number: **10190575.0**

(22) Date of filing: **09.11.2010**

(51) Int Cl.:
H01P 1/208 ^(2006.01) ***H01P 7/06*** ^(2006.01)

(54) **Super Q dual mode cavity filter assembly**

Super-Q-Dualmoden-Hohlraumfilteranordnung

Ensemble de filtre de cavité à mode double Q super

(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

(30) Priority: **20.09.2010 US 886168**

(43) Date of publication of application:
21.03.2012 Bulletin 2012/12

(73) Proprietor: **COM DEV International Ltd.**
Cambridge,
Ontario N1R 7H6 (CA)

(72) Inventors:
- **Yassini, Bahram**
  Waterloo, Ontario N2V 2T3 (CA)
- **Yu, Ming**
  Waterloo, Ontario N2T 1S1 (CA)

(74) Representative: **Sadler, Peter Frederick et al**
Reddie & Grose LLP
16 Theobalds Road
London WC1X 8PL (GB)

(56) References cited:
EP-A1- 0 751 579 **EP-A2- 0 250 857**
WO-A1-02/093681 **US-A- 5 254 963**

- **YASSINI B ET AL: "A Ku-band high-Q tunable filter with stable tuning response", IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES DECEMBER 2009 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS INC. USA, vol. 57, no. 12, December 2009 (2009-12), pages 2948-2957, XP002622567, DOI: DOI:10.1109/TMTT.2009.2034215**

Printed by Jouve, 75001 PARIS (FR)

Description

FIELD

[0001] Embodiments described herein relate generally to microwave resonator filters and, more particularly, to dual mode microwave resonator filters exhibiting low loss at very high frequency ranges.

INTRODUCTION

[0002] A microwave filter is an electromagnetic device that can be tuned to pass energy within bands of frequencies encompassing resonant frequencies of the filter, while substantially suppressing inter-band frequencies. The resulting bandpass characteristic of the microwave filter can be described by one or more different performance criteria. For example, insertion loss describes the amount of signal loss exhibited in the microwave filter's passband, rejection (or "isolation") describes the amount of signal attenuation exhibited in the filter's stopband, return loss relates to the ratio of signal power incident on and reflected from the filter, loss variation (sometimes referred to as "ripple") describes the flatness of the passband, and group delay is related to the phase characteristics of the filter throughout the passband.

[0003] One commonly used performance characteristic of microwave filters is the so-called quality ("Q") factor of the filter. The Q factor of a microwave resonator can be related to the proportion of energy stored by the resonator in relation to its losses. For a microwave filter realized using one or more resonators, the Q factor also provides a relation between the passband and centre frequency of the filter, as well as being related to both the insertion loss and pass-band flatness exhibited by the realized microwave filter. Generally, microwave filters having higher Q factors tend to have lower insertion loss and steeper roll-off in the transitional band between the filter's passband and the stopband, which result in a more square-shaped passband response. In contrast, filters having lower Q factors tend to exhibit increased insertion loss and a more gradual transitional band roll-off, which both decreases efficiency and increases inter-channel distortion (for example, if the filter is being deployed in a channel multiplexer). For at least these reasons, high Q factor filters may be preferably used in some telecommunications applications where excessive inter-channel distortion can be undesirable or is not permitted. Waveguide (hollow cavity) and dielectric resonator filters are two examples of generally high Q factor microwave filters. Depending on the application, Q factors on the order of about 8,000 to 16,000 can be realized using hollow cavity and dielectric resonator topologies,

[0004] EP 0 250 857 describes a microwave filter composed of at least two cavity resonators, with a coupling aperture between resonators for coupling microwave energy. One of the cavity resonators is operative to propagate microwave energy having a TE mode and the other of the cavity resonators being operative to propagate microwave energy having at TM mode. European patent application EP 0 751 579 describes a microwave filter having at least two resonators with at least two degenerated wave types resonance-capable in one resonator. The resonators are coupled so that possible couplings of the degenerated wave types are only overcouplings that are located outside the resonator. International application WO 02/093681 describes a microwave filter having a plurality of cavity resonators which couple magnetic field components in electrically adjacent cavity resonators to one another with at least one further plate for coupling field components in electrically non-adjacent cavity resonators to one another. None of the above-mentioned documents disclose resonance modes comprising a dual TE_{22N} mode.

SUMMARY

[0005] In one broad aspect, some embodiments provide a microwave resonator assembly comprising: a cavity defined by an electrically conductive cylindrical enclosure in which electromagnetic energy radiated into the cavity resonates in a plurality of resonance modes comprising a dual TE_{22N} mode, N greater than or equal to one; an input port provided in the cylindrical enclosure for radiating a first TE_{22N} mode having a first polarization into the cavity; and a discontinuity formed within the cavity configured to electromagnetically couple the first TE_{22N} mode with a second TE_{22N} mode having a second polarization orthogonal to the first polarization.

[0006] In another broad aspect, some embodiments provide a microwave resonator filter comprising: a plurality of cavities including at least a first cavity and a second cavity located adjacent to the first cavity, each of the first cavity and the second cavity defined by a corresponding electrically conductive cylindrical enclosure in which electromagnetic energy radiated into that cavity resonates in a plurality of resonance modes comprising a dual TE_{22N} mode, N greater than or equal to one; and at least one coupling element for radiating electromagnetic energy between the first cavity and the second cavity, the at least one coupling element configured to electromagnetically couple a first TE_{22N} mode resonating in the first cavity with a fourth TE_{22N} mode resonating in the second cavity, and a second TE_{22N} mode resonating in the first cavity with a third TE_{22N} mode resonating in the second cavity, the first and fourth TE_{22N} modes having a first polarization and the second and third TE_{22N} modes having a second polarization orthogonal to the first polarization.

[0007] These and other aspects are set forth herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] A detailed description of various embodiments is provided herein below with reference to the following drawings, by way of example only, and in which:

FIGS. 1A and 1B are perspective and top views of a microwave resonator assembly;

FIG. 2 is a diagram showing expected field patterns of the dual TE_{22N} mode when excited in the microwave resonator assembly of FIGS. 1A and 1B;

FIG. 3 is a schematic diagram showing alternative locations for an input port included in the microwave resonator assembly of FIGS. 1A and 1 B;

FIGS. 4A and 4B are schematic diagrams showing alternative locations for a coupling screw included in the microwave resonator assembly of FIGS. 1A and 1B;

FIGS. 5A and 5B are schematic diagrams showing alternative locations for a transverse angular or radial iris included in the microwave resonator assembly of FIGS. 1A and 1B;

FIGS. 6A-6F are schematic diagrams showing some illustrative combinations of the transverse angular and radial irises shown in FIGS. 5A and 5B;

FIGS. 7A and 7B are schematic diagrams showing alternative, end-launch locations for the input port shown in FIG. 3;

FIGS. 8A and 8B are schematic diagrams showing alternative locations for a tuning screw included in the microwave resonator assembly of FIGS. 1A and 1 B;

FIGS. 9A-9C are perspective, top and side views of a 4-pole microwave resonator filter constructed using the microwave resonator assembly of FIGS. 1A and 1B;

FIGS. 10A and 10B are perspective and top views of an alternative configuration of the microwave resonator assembly of FIGS. 1A and 1B having sidewall mounted coupling elements;

FIGS. 11A and 11B are perspective and top views of another alternative configuration of the microwave resonator assembly of FIGS. 1A and 1B having sidewall mounted coupling elements;

FIGS. 12A and 12B are top and perspective views of a 4-pole, planar-mounted microwave resonator filter constructed using the microwave resonator assembly of FIGS. 10A and 10B;

FIGS. 13A and 13B are top and perspective views of an alternative configuration of a 4-pole, planar-mounted microwave resonator filter constructed using the microwave resonator assembly of FIGS. 10A and 10B;

FIGS. 14A and 14B are top and perspective views of a 4-pole, planar-mounted microwave resonator filter constructed using the microwave resonator assembly of FIGS. 11A and 11B;

FIGS. 15A and 15B are top and perspective views of a 4-pole, planar-mounted microwave resonator filter constructed using an alternative configuration of the microwave resonator assembly of FIGS. 10A and 10B;

FIGS. 16A and 16B are top and perspective views of a 2-pole, single-cavity microwave resonator filter; and

FIGS. 17A-D are top and side views of alternative cavity geometries for a microwave resonator assembly.

[0009] It will be understood that reference to the drawings is made for illustration purposes only, and is not intended to limit the scope of the embodiments described herein below in any way. For convenience, reference numerals may also be repeated (with or without an offset) throughout the figures to indicate like or analogous components or features.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Microwave resonator filters are commonly designed to operate in the TE_{11N} or TE_{011} mode for high Q factor applications because, at lower frequency ranges, such as the C band (4-8 GHz) or the K_u band (12-18 GHz), the TE_{11N} or TE_{011} modes can offer better performance than other resonance modes. For example, low loss filters having Q factors up to about 16,000 are realizable using the TE_{11N} or TE_{011} modes. Quality factors up to and exceeding those realizable using the TE_{11N} or TE_{011} modes of the same or higher order can be also achieved by designing the microwave filter to operate in higher order resonance modes, such as the TE_{22N} mode. However, for microwave filters designed for the C or K_u bands, the realized TE_{22N} mode filter tends to be larger and bulkier as compared to the TE_{11N} or TE_{011} modes. In certain telecommunications applications, such as satellite or spacecraft installations, where size and weight can be important design constraints, the additional weight and bulk incurred by the TE_{22N} mode filter may represent a significant overall cost. Often at the lower C and K_u band frequencies, Q factors higher than 16,000 are unnecessary.

[0011] Depending on the application, however, at higher frequency ranges, such as the K band (18-27 GHz), microwave resonator filters realized using higher order resonance modes can begin to offer competitive design considerations. Although TE_{22N} mode filters remain generally larger and bulkier, the size penalty between the higher order and lower order mode filters usually preferred at lower frequencies is not as dramatic at the higher K band frequencies. Given that the TE_{22N} mode can achieve comparable or even superior Q factors, for higher frequency band applications, the superior Q factor offered by the TE_{22N} mode may be traded off against the size penalty incurred relative to the TE_{11N} or TE_{011} modes. For example, Q factors of about 25,000 are realizable in 20 GHz, TE_{22N} type filters.

[0012] The described embodiments provide a microwave resonator filter that operates in the dual TE_{22N} mode to realize a very high Q factor at very high frequency ranges. The microwave resonator filter can comprise one or more cylindrical cavities in which two orthogonal field polarizations of the TE_{22N} mode can be excited and coupled together using a suitably located coupling element. Different combinations of inter-cavity irises provide for both direct and cross-coupling of aligned field polarizations, as required, to realize complex filter functions, such as elliptical or Chebyshev functions, as well as other functions. Negative mode coupling also allows for transmission zeros to be realized on either side of the filter passband.

[0013] Referring initially to FIGS. 1A and 1B, there is shown a microwave resonator assembly 50 in perspective and top views. The microwave resonator assembly 50 is formed using a cylindrical enclosure 52, which can be constructed out of a suitable metal or other electrically conductive material. For example, the cylindrical enclosure 52 can be constructed out of aluminum, which is commonly used for spacecraft and other telecommunication applications due to its comparatively lightweight. As an alternative to aluminum, conductive materials having lower coefficients of thermal expansion, including nickel-steel alloys such as INVAR, can be used to form the cylindrical enclosure 52 to obviate or at least reduce the need for temperature compensation devices to be incorporated into the microwave resonator assembly 50. However, whether aluminum or nickel-steel alloy is used, temperature compensative devices may be used. The nickel-steel alloys also tend to be denser, more expensive and more difficult to machine than aluminum. In some cases, the conductive properties of the cylindrical enclosure 52 can be improved by adding a thin coating of silver, for example, or some other metal having better conductive properties than the base metal used to form the cylindrical enclosure 52.

[0014] The cylindrical enclosure 52 includes a cylindrical sidewall 54 extending between opposing end walls 56 and 58 and is hollow, thereby defining a cavity 60 in the interior space of the cylindrical enclosure 52. Any suitable technique for forming the cylindrical enclosure 52 may be used. For example, the cylindrical sidewall 54 and end wall 56 can be formed or shaped into a unitary piece of metal, with the opposing end wall 58 formed as a separate piece and attached to the cylindrical sidewall 54 after the fact. As will be appreciated, a metallic weld or alternatively mechanical fasteners (e.g., screws) can be used for this purpose. In the latter case, a mounting flange or lip (not shown) can also be incorporated into the sidewall 54 adjacent to where the connection is made with the end wall 58. Screw holes (not shown) aligned with corresponding screw mounts in the flange can also be bored or otherwise formed in the end wall 58 for making the mechanical connection. Of course, other techniques for forming the cylindrical enclosure 52 may also be apparent.

[0015] As illustrated in FIGS. 1A and 1B, the cylindrical enclosure 52 has a circular cross-section defined by a radius (R) 62 extending outwardly in a transverse plane in all directions from a longitudinal axis 64 of the cylindrical enclosure 52. Alternatively, the cross-section of the cylindrical enclosure 52 can also be some pseudo-circular shape, such as an octagon or higher-degree polygon, which exhibits 90-degree radial symmetry and thereby approximates the boundary conditions presented by a perfectly circular cross-section. In such alternative configurations, the cross-section of the cylindrical enclosure 52 can be characterized by an effective radius, as opposed to a true radius, (i.e., which approximately defines the shortest distance between the longitudinal axis 64 and any point on the inner sidewall 54). As used herein throughout, the term 'cylindrical' should be understood as including both circular pseudo-circular geometries, as noted above.

[0016] Input port 66 is provided in the cylindrical enclosure 52 for radiating electromagnetic energy into the cavity 60 from an external waveguide section 68 or coaxial cable (not shown). Different structures can also be utilized for realizing the input port 66, as will be appreciated. In the embodiment explicitly shown in FIGS. 1A and 1B, input port 66 is formed as an aperture (or iris) extending completely through the sidewall 54 to form a continuous volume between the external waveguide section 68 and the cavity 60. With this arrangement, electromagnetic waves transmitted along the waveguide section 68 are coupled into the cavity 60 due to field interactions between the electromagnetic energy inside the cavity 60 and the incident electromagnetic wave. Alternatively, a coaxial coupler, comprising an outer cylindrical conductor separated from an interior conductive probe by a dielectric mounting plate, or some other suitably configured electromagnetic probe can be used to couple electromagnetic energy into the cavity 60.

[0017] It should be appreciated that the designation of an "input" port is somewhat arbitrary and made only for the sake of clarity. Depending on the particular application to which the resonator assembly 50 is put, the input port 66 could instead be used as an output port for radiating stored electromagnetic energy out of the cavity 60 to the external waveguide section 68. However, in the event that the resonator assembly 50 is used to realize a non-symmetrical filter (containing distinct "input" and "output" ports), the designation of input port 66 as such will be followed throughout. It should also be appreciated that the input port 66 may be used to couple the cavity 60 with some microwave component other than external waveguide section 68, such as a second cavity located adjacent to the first cavity 60, and thereby used to radiate electromagnetic energy between the two adjacent cavities 60, as in a multi-cavity microwave resonator filter.

[0018] Referring now to FIG. 2, electromagnetic energy radiated into the cavity 60 can be excited into an infinite number of different resonance modes, each of which is characterized by a corresponding resonant frequency and is supported by the particular geometry of the cavity 60. In general, microwave filters are designed to operate in only one particular resonance mode, which defines a frequency range of operation for the filter, for example in terms of a centre frequency and bandwidth. Other unwanted (or spurious) modes appearing in the cavity and characterized by other resonant frequencies, therefore, represent an effective limit on the operational range of the filter. In addition to the TE_{11N} and TE_{011} modes commonly used in lower frequency telecommunications applications, the cylindrical shape of the cavity 60 also supports the TE_{22N} dual resonance mode. As will be appreciated, the third co-efficient index, "N", indicates the repetition rate (in terms of half wavelengths) of the resonance mode's electromagnetic field pattern in the axial direction and can be any integer greater than or equal to one. The cylindrical geometry of the cavity 60 supports all TE_{22N} modes, although as a practical matter, the TE_{221} mode may be preferred to other higher modes for its larger spurious free range as compared to higher TE_{22N} modes. A mode chart can be consulted for a complete listing of resonance modes supported by the cavity 60.

[0019] Owing to the 90-degree radial symmetry of the cavity 60, two distinct TE_{22N} modes may be excited in the cavity 60. Thus, the TE_{22N} mode can be referred to as a dual mode to reflect the fact that two electromagnetic resonators having the same resonant frequency are supported simultaneously by one physical cavity. Relative to the first TE_{22N} mode 70 (leftmost field pattern shown in FIG. 2), the second TE_{22N} mode 72 (field pattern shown in FIG. 2) has the same electromagnetic field pattern, but an orthogonal polarization. As will be appreciated and as used herein throughout, two modes are referred to as being "orthogonal" modes, if for a perfectively symmetrical cavity, the respective E and H field components of the two modes are oriented 90-degrees relative to one another at all points within the cavity. As the two TE_{22N} modes 70 and 72 are "orthogonal" to one another, they naturally co-exist within the cavity 60 without substantial field interactions, so that electromagnetic energy excited in one of the TE_{22N} modes 70 and 72 is contained within that given mode and, in the absence of a discontinuity or coupling element formed within the cavity 60, would not leak over into the other "orthogonal" mode.

[0020] Using the two characterizing vectors 74 and 76 to establish a reference angular position within the cavity 60, the second TE_{22N} mode 72 is 45-degrees offset from the first TE_{22N} mode 70 in the transverse plane to the longitudinal axis 64 of the cavity 60. (In other words, a 45-degree angle is formed between the two characterizing vectors 74 and 76). The choice of the two characterizing vectors 74 and 76 is somewhat arbitrary because, owing to the 90-degree radial symmetry of the first and second TE_{22N} modes 70 and 72, any one of 4 different vectors (shown in FIG. 2) can be selected for each TE_{22N} mode 70 and 72 to serve as the characterizing vector. In either case, the set of 4 vectors are oriented 90-degrees offset from one another. For sake of clarity, reference will simply be made to the characterizing vectors 74 and 76, which can be any of the vectors illustrated in FIG. 2.

[0021] Referring back to FIGS. 1A and 1B, electromagnetic energy radiated into the cavity 60 through the input port 66 will be excited into one of the two TE_{22N} modes 70 or 72 (shown in FIG. 2), if the incident electromagnetic wave is radiated at or near to the resonant frequency of the TE_{22N} dual mode. Which of the two orthogonal polarizations is excited within the cavity 60 can depend on the particular mechanism of input coupling and the angular position of the input port 66 in relation to the two characterizing vectors 74 and 76, as will be explained in more detail below. The other of the two TE_{22N} modes 70 or 72 not directly coupled to the input port 66 is simultaneously excited within the cavity 60 by forming at least one discontinuity within the cavity 60 at a corresponding location within the cavity 60, where each of the TE_{22N} modes 70 and 72 have non-zero field components. For example, coupling of the two TE_{22N} modes 70 and 72 is accomplished using one or more coupling screws 78 projecting through the sidewall 54 (or alternatively end walls 56 or 58) into the interior of the cavity 60. Alternatively, other structures that disturb the radial symmetry of the cavity 60 can be used to provide intra-cavity coupling between the two orthogonal TE_{22N} modes 70 and 72, including deformations (convex or concave) formed in the sidewall 54, dielectric blocks mounted within the cavity 60 or other dielectric boundary conditions, and the like. The term "discontinuity" is understood to encompass each of the above-noted disturbances to the 90-degree radial symmetry of the cavity 60.

[0022] Tuning screws 82 and 80, which like the coupling screws 78 project through the sidewall 54 into the interior of the cavity 60, are used for making fine adjustments to the resonant frequencies of the first and second TE_{22N} modes 70 and 72, respectively. The location of the tuning screws 82 and 80 within the cavity 60 determines which of the two orthogonal TE_{22N} modes 70 and 72 are affected. For example, the tuning screw 82 is used to adjust the resonant frequency of the first TE_{22N} mode 70 (defined by characterizing vector 74) and has comparatively less effect on the resonant frequency of the second TE_{22N} mode 72 (defined by characterizing vector 76). On the other hand, the tuning screw 80, which is located at a 45 degree angular offset from the tuning screw 82 is used to adjust the resonant frequency of the second TE_{22N} mode 72, while having comparatively little effect on the resonant frequency of the first TE_{22N} mode 70. The tuning screws 82 and 80 therefore provide relatively independent tuning of the first and second TE_{22N} modes 70 and 72 and can be used, for example, to compensate for resonant frequency shifting caused by other components of the resonator assembly 50, such as input port 66, coupling screws 78, etc.

[0023] The resonator assembly 50 also includes at least one coupling element for radiating electromagnetic energy out of the cavity 60 (e.g., into an adjacent cavity to realize a multi-cavity filter having 4 or more poles). In the embodiment explicitly shown in FIGS. 1A and 1B, the resonator assembly 50 includes radial iris 84 and radial irises 86. As will be explained in more detail below, the angular position of the radial irises 84 and 86 in relation to the characterizing vectors 74 and 76 determines which of the two TE_{22N} modes 70 and 72 are predominantly coupled. As shown, the radial iris 84 couples the first TE_{22N} mode 70, due to its angular position within the cavity 60, while providing substantially less coupling of the orthogonal TE_{22N} mode 72. Moreover, the two radial irises 86 (which are each located at a 45-degree angular offset from the radial iris 84) achieve the opposite effect of coupling the second TE_{22N} mode 72 predominantly while providing substantially less coupling of the orthogonal TE_{22N} mode 70. The size and location of the radial irises 84 and 86 also determine the amount of coupling between aligned modes in adjacent cavities, as will be explained in more detail below.

[0024] Although not explicitly illustrated in FIGS. 1A and 1B, a temperature compensation device can also be included in the microwave resonator assembly 50. The temperature compensation device can be used to stabilize the resonant frequency of the TE_{22N} modes 70 and 72 over a range of different operating temperatures as follows. When the resonator assembly 50 is subjected to a temperature gradient, the material used to form the cylindrical enclosure 52 will expand or contract according to its co-efficient of thermal expansion. For example, aluminum has a relatively large co-efficient of thermal expansion as compared to the temperature stabilized nickel-steel alloys. Expansion or contraction of the cylindrical enclosure 52 causes a corresponding change in the volume of the cavity 60 defined therewithin. Since the resonant frequency of the dual TE_{22N} mode is related to the volume of the cavity 60, without some form of temperature compensation, that frequency can "drift" about its centre point over the range of operating temperatures as the cavity 60 expands and contracts.

[0025] As will be appreciated, different approaches to providing temperature compensation in the resonator assembly 50 are possible. For example, a temperature compensation device can be mounted to the exterior portion of end wall 56 or 58, whichever is free and not used for external mounting of the resonator assembly 50. The temperature compensation device can comprise a strap or end cap assembly of a comparatively low thermal expansion material coupled to the exterior wall portion, so that as the operating temperature of the resonator assembly 50 increases, the strap or end cap assembly exerts a force on the end wall 56 or 58 to bend or flex the end wall 56 or 58 inwardly. The corresponding decrease in cavity volume due to the inward flexing of the end wall 56 or 58 counterbalances the corresponding increase in cavity volume due to radial expansion of the cavity 60, thereby maintaining an essentially constant cavity volume over the entire operating range of the resonator assembly 50. Accordingly, for both planar and stack-up (collinear) configurations having side launch termination (i.e., input/output coupling provided in the sidewall 54), the resonator assembly 50 can accommodate a temperature compensation device to adjust an exposed end wall 56 or 58 and, consequently, the axial length of the cavity 60 in order to compensate frequency drift due to temperature gradients. While the strap or end cap assembly explicitly described above represents one possible temperature-compensating device, still other mechanisms for providing temperature compensation may be apparent.

[0026] Referring now to FIG. 3, different locations for the input port 66 within the cavity 60 are possible because of the 90-degree radial symmetry of the TE_{22N} dual mode. Four such locations for the input port 66 are shown in FIG. 3, spaced 90-degrees apart from each other, at locations within the cavity 60 having an angular position, in relation to the characterizing vector 76, equal to an integer multiple of 90 degrees. As used herein throughout, the term "integer multiple" should be understood as including every whole number multiple, positive and negative, as well as zero. In general, when the input port 66 is realized using an iris or aperture defined through the sidewall 54, the characterizing vector of the coupled TE_{22N} mode will be offset essentially 45-degrees from the input port 66, plus an integer multiple of 90 degrees, regardless of the absolute angular position of the input port 66 within the cavity 60. Thus, each of the four locations for the input port 66 explicitly shown in FIG. 3 would be suitable for exciting the first TE_{22N} mode 70 as these locations are 45-degrees offset from the characterizing vectors 74 shown in FIG. 2. It follows also that by rotating the angular position of the input port 66 within the cavity 60 by 45 degrees, relative to one of the locations explicitly shown in FIG. 3, the input port 66 would be made suitable for exciting the second TE_{22N} mode 72 defined by the second characterizing vector 76. Of course, it should be appreciated that the terms "first" and "second" are used herein throughout only to distinguish between the two orthogonal polarizations of the dual TE_{22N} mode.

[0027] Referring now to FIGS. 4A and 4B, the 90-degree symmetry of the dual TE_{22N} mode also results in different possible locations for the coupling screw 78 (or 79) to be formed within the cavity 60 for coupling together the two orthogonal TE_{22N} modes 70 and 72. More generally, any electromagnetic discontinuity, such as those described above, can be formed at the locations indicated. To provide good intra-cavity mode coupling, the electromagnetic discontinuity, or discontinuities, should be formed at a location within the cavity 60 where each of the orthogonal TE_{22N} modes 70 and 72 have non-zero field components, so that by perturbing the field pattern of the first TE_{22N} mode 70, an appreciable amount of electromagnetic energy will transfer into the orthogonal polarization and thereby indirectly excite the second TE_{22N} mode 72. A single coupling screw 78 (or 79) can be projected into the cavity 60 at one of the locations indicated, depending on the particular application, if the single coupling screw 78 or 79 provides the required amount of mode coupling. However, multiple screws 78 (such as the two screws 78 seen in FIGS. 1A and 1B), or other discontinuities, can be included in the resonator assembly 50 to increase coupling of the two TE_{22N} modes 70 and 72 as required.

[0028] Using the characterizing vectors 74 and 76 as reference angular positions, the coupling screw 78 can be located so as to have an angular position within the cavity 60 that is substantially intermediate the two characterizing vectors 74 and 76. In a particular case, the coupling screw 78 can be located at the angular midpoint between the two characterizing vectors 74 and 76, so that the angular position of the coupling screw 78 bisects the 45-degree angle formed between the two characterizing vectors 74 and 76, 22.5 degrees offset from each respective vector. Although it is not strictly necessary for the coupling screw 78 to be located at the precise angular midpoint between the two characterizing vectors 74 and 76, for good coupling between the orthogonal TE_{22N} modes 70 and 72, the angular spacing of the coupling screw 78 from each characterizing vector 74 and 76 can be more than minimal. A screw or other electromagnetic discontinuity aligned with either of the two characterizing vectors 74 or 76 would provide substantially less coupling of the two TE_{22N} modes 70 than does the coupling screw 78 when positioned intermediate the two characterizing vectors 74 and 76.

[0029] It will also be understood that the axial position of the coupling screw 78 is optimizable and can depend on the axial repetition rate of the dual TE_{22N} mode field pattern (i.e., the value of "N"), depending on the amount of coupling required for the particular application. Since each increment of "N" represents one half-wavelength in the axial field pattern of the dual TE_{22N} mode, the order of the TE_{22N} prescribes certain E-field maxima along the axial length of the cavity 60, and based upon which the coupling screw 78 can be located to provide good coupling. As will be appreciated, the TE_{221} mode has one E-field maximum located at the axial midpoint of the cavity 60, the TE_{222} mode has two E-field maxima located at the one and three-quarter heights of the cavity 60 and, in general, the TE_{22N} mode has E-field maxima located at odd integer multiples of one-quarter wavelength. The coupling screw 78 may conveniently be located at these axial positions exhibiting respective E-field maxima, although it is not necessary and other axial locations can provide sufficient coupling as well. Accordingly, the range of suitable locations for the coupling screw 78 can be generalized to include a plurality of different locations within a wedge of the cavity 60, defined by the longitudinal axis 64, the two characterizing vectors 74 and 76, and the arcuate portion of the sidewall 54 subtended between the two characterizing vectors 74 and 76.

[0030] Again owing to the 90-degree radial symmetry of the dual TE_{22N} mode, the one or more electromagnetic discontinuities used for inter-mode coupling can be formed at different locations within the cavity 60. Eight exemplary locations are illustrated in FIGS. 4A and 4B, which are separated into two sets of four locations each based on the relative sign of the inter-mode coupling that is realized at each respective location. Coupling screws 78 are spaced 90-degrees apart from each other and at angular positions, in relation to the first characterizing vector 74, equal to negative 22.5 degrees plus an integer multiple of 90 degrees. Coupling screws 79 are also spaced 90-degrees apart from each other but are located at angular positions, in relation to the first characterizing vector 74, equal to positive 22.5 degrees plus an integer multiple of 90 degrees. Thus, the set of coupling screws 79 is 45-degrees offset with respect to the set of coupling screws 78. Consequently, for a given polarity of the TE_{22N} mode 70, the corresponding polarity of the TE_{22N} mode 72 when excited by the coupling screws 78 will be opposite to that of the TE_{22N} mode 72 when excited by the coupling screws 79. (It is noted that the angular positions of coupling screws 78 and 79 could equivalently be defined in relation to the characterizing vector 76 and is defined with reference to characterizing vector 78 for convenience only.)

[0031] Referring now to FIGS. 5A and 5B, one or more different coupling elements can be included in the resonator assembly 50 for radiating one or both of the TE_{22N} modes 70 and 72 out of the cavity 60. The coupling elements can be provided in either the sidewall 54 or the end wall 58 in different configurations of the resonator assembly 50. In each case, the shape and location (axial and angular) of the coupling element within the cavity 60 can influence the amount of coupling achieved with respect to each of the two orthogonal TE_{22N} modes 70 and 72. Coupling elements formed at certain locations and angular positions within the cavity 60 also couple one of the TE_{22N} modes substantially more than the other orthogonal mode. The iris configurations illustrated in FIG. 5A provide relatively more coupling of the first TE_{22N} mode 70 defined by characterizing vector 74, while those illustrated in FIG. 5B provide relatively more coupling of the second TE_{22N} mode 72 defined by characterizing vector 76.

[0032] As seen in FIG. 5A, radial iris 84 is formed in the end wall 58 having an angular position equal to an integer multiple of 90-degrees, in relation to the second characterizing vector 76. Four such locations for the radial iris 84 are indicated due to 90-degree radial symmetry in the cavity 60, namely at 0, 90, 180 or 270 degrees (and hence at integer multiples of 90 degrees) offset from the second characterizing vector 76. Each of the radial irises 84 has a generally rectangular shape forming an elongated, slot-shaped aperture extending predominantly outwardly from the longitudinal axis 64 of the cavity 60 in the radial direction. Thus, the radial iris 84 can be substantially aligned with the effective radius 62 but can also have some radial skew or yaw. The radial iris 84 can have square corners as shown or alternatively can have rounded edges to realize a higher Q factor. The centre of the radial iris 84 is spaced apart from the longitudinal axis 64 by a radial distance of approximately 0.728R, where R is the actual or effective radius of the cavity 60. As can be seen from FIG. 2, for example, at this radial distance (and angular position with the cavity 60), the first TE_{22N} mode 70 has relatively dense E-field lines extending orthogonal to the radial iris 84, indicating that a radial iris 84 having the radial spacing, orientation and angular position shown in FIG. 5A would provide good coupling of the first TE_{22N} mode 70.

[0033] While a radial distance of 0.728R represents one possibility, the spacing for the radial iris 84 is optimizable to fit the particular microwave application. For example, the relatively strong coupling achieved when the radial iris 84 is spaced at 0.728R from the longitudinal axis 64 can make this radial position suitable for wideband applications. Other radial positions spaced apart from the 0.728R point may otherwise be suitable for narrowband applications due to the relatively weaker coupling that can be expected at these other radial positions. Accordingly, a radial spacing greater than about 0.455R may be appropriate for different applications. The length of the radial iris 84 can also be adjusted as needed when the radial iris 84 is shifted away from the 0.728R point to compensate for some of the consequent loss of bandwidth. Moreover, depending on bandwidth requirements, the radial iris 84 can also be located (not shown) at a radial distance of about 0.25R, or more generally between about 0.1R to 0.4R. This approximate range may be suitable again for some more narrowband applications. As will be appreciated, the radial iris 84 can also have different shapes other than rectangular, such as a triangle or sector.

[0034] In addition to, or in place of, the radial iris 84, transverse angular iris 88 is also suitable for coupling the first TE_{22N} mode 70. Transverse angular iris 88 is formed in the end wall 58 having an angular position equal to an integer multiple of 90-degrees, in relation to the first characterizing vector 74. Thus, again four different locations for the transverse angular iris 88 are indicated due to 90-degree radial symmetry in the cavity 60, which occur at 0, 90, 180 or 270 degrees offset from the first characterizing vector 74. Each of the transverse angular irises 88 shown have a generally rectangular shape, but elongated now in a direction transverse to the real or effective radius of the cavity 60 (i.e., in an "angular" or "tangential" direction). The centre of each transverse angular iris 88 is shown spaced apart from the longitudinal axis 64 by a radial distance of approximately 0.455R. The relatively dense, orthogonal E-field lines of the first TE_{22N} mode 70 (FIG. 2) at these radial and angular positions again indicate their suitability for coupling the first TE_{22N} mode.

[0035] Like the radial iris 84, the radial spacing of the transverse angular iris 88 is also optimizable to fit the particular microwave application. While a radial spacing of 0.455R may be suitable for wideband applications, a radial distance of between about 0.25R and 0.728R for the transverse angular iris 88 may still be suitable for some narrowband applications. Optionally, the length of the transverse angular iris 88 can also be adjusted to control the achievable bandwidth. A separate range of radial distances of between about 0.85R and the sidewall 54 (i.e., greater than 0.85R) may also be suitable for some narrowband applications, due to the relatively weaker coupling that can be expected at these other radial positions in comparison to have 0.455R when the E-field lines of the first TE_{22N} mode are denser. The transverse angular iris 88 can be rectangular (as shown) or arcuate in a trajectory tangential to the sidewall 54, and can have some angular skew or be substantially orthogonal to the effective radius 62. The edges of the transverse angular iris 88 can also be square or rounded to realize a higher Q factor.

[0036] FIG. 5B shows radial irises 86 and transverse angular irises 90, similar to the radial irises 84 and 88 illustrated in FIG. 5A, but at locations within the cavity 60 that are suitable for coupling the second TE_{22N} mode 72 defined by characterizing vector 76 (as opposed to the first TE_{22N} mode 70 defined by characterizing vector 74). Radial irises 86 are located at an angular position equal to an integer multiple of 90-degrees in relation to the first characterizing vector 74, and are therefore 45-degrees offset with the radial irises 84. However, like radial irises 84 suitable for coupling the first TE_{22N} mode 70, the radial irises 86 can be located at a radial distance from the longitudinal axis 64 equal to any of the distances or ranges discussed above depending on the application and bandwidth requirements of the resonator assembly 50. In the exemplary case illustrated, each radial iris 86 can be centered at a radial distance approximately equal to 0.728R.

[0037] The transverse angular irises 90 shown in FIG. 5B are located at an angular position equal to an integer multiple of 90-degrees in relation to the second characterizing vector 76, which is 45-degrees offset with respect to the transverse angular irises 88. The approximate radial distances and ranges indicated for the transverse angular iris 88 also apply to the transverse angular irises 90, except that transverse angular irises 90 provide good coupling of the second TE_{22N} mode 72 at these locations within the cavity 90. The particular radial distance selected for the transverse angular iris 90 can again depend on bandwidth requirements or other factors. In an exemplary case, the transverse angular iris 90 can be located at about 0.455R, where R is the effective radius of the cavity 60.

[0038] Referring now to FIGS. 6A-6F, there are illustrated some exemplary combinations of coupling elements that can be formed in the end wall 58 for radiating one or both of the TE_{22N} modes 70 and 72 out of the cavity 60. It should be appreciated that the examples shown in FIGS. 6A-6F are illustrative only and not to be understood as representing an exhaustive set of all possible combinations of coupling elements. As can be seen from the example configurations shown, the number and location of each type of coupling element is optimiziable to provide different strengths and relative proportions of coupling. In some cases, a single coupling element may be used to couple a given TE_{22N} mode (either the first TE_{22N} mode 70 or the second TE_{22N} mode 72, as the case may be). In other cases, multiple coupling elements can be used simultaneously to provide greater amounts of coupling. As examples only, the set of coupling elements formed in the end wall 58 can also include all radial irises, all transverse angular irises, or a mix of radial and transverse angular irises, in addition to other shapes or orientations of coupling elements.

[0039] The combination shown in FIG. 6A includes a radial aperture 84 together with a pair of radial apertures 86 located at a 45-degree angular offset (positive and negative, respectively) from the radial aperture 84. The radial aperture 84 (aligned with the characterizing vector 76) couples the first TE_{22N} mode 70, while the radial apertures 86 (an integer multiple of 90-degrees offset from the characterizing vector 74) jointly couple the second orthogonal TE_{22N} mode 72. The combination in FIG. 6B is similar to that shown in FIG. 6A, but now includes a pair of radial irises 84 together with two pairs of radial irises 86 arranged diametrically opposed. Again the radial irises 84 provide coupling of the first TE_{22N} mode 70, while the radial irises 86 provide coupling of the second TE_{22N} mode 72. The combinations shown in FIGS. 6A and 6B are two examples of coupling being provided by all radial irises 84 or 86.

[0040] In FIG. 6C, a single radial iris 84 aligned with the characterizing vector 76 for coupling the first TE_{22N} mode 70 is combined with a single transverse angular iris 90, which is also aligned with the characterizing vector 76 and therefore provides coupling of the second TE_{22N} mode 72. In FIG. 6D, four such combinations of a radial iris 84 and transverse angular iris 90 are formed in the end wall 58, each combination of a radial iris 84 and transverse angular iris 90 spaced apart from each other combination within the cavity 60 by 90-degree angular offsets. Accordingly, each radial iris 84 predominantly couples the TE_{22N} mode 70 and each transverse angular iris 90 predominantly couples the orthogonal TE_{22N} mode 72.

[0041] It is also possible to utilize all transverse angular irises 88 and 90, as shown in FIGS. 6E and 6F. The combination in FIG. 6E includes a pair of transverse angular irises 90 suitable for coupling the second TE_{22N} mode 72, together with two pairs of transverse angular irises 88 suitable for coupling the first TE_{22N} mode 70. As will be understood, each transverse angular iris 88 is located an integer multiple of 90 degrees offset in relation to the first characterizing vector 74, and likewise for each transverse angular iris 90 in relation to the second characterizing vector 76. The combination of coupling elements shown in FIG. 6F is similar to that shown in FIG. 6E, but includes only a single transverse angular iris 90 and a pair of transverse angular irises 88.

[0042] Referring now to FIGS. 7A and 7B, input coupling into the cavity 60 can also be accomplished using an input port 92 or 94 formed in the end wall 56 of the cylindrical enclosure 52, as an alternative to the input port 66 formed in the sidewall 54. The locations of the input ports 92 and 94 are similar to the transverse irises 88 and radial irises 84 (FIG. 5A), but formed in the end wall 58 rather than the end wall 56. As shown in FIG. 7A, an input port 92 can be formed in the end wall 56 at a location having an angular position, in relation to the first characterizing vector 74, equal to an integer multiple of 90 degrees. The input port 92 is formed out of an elongated iris oriented generally transverse to the effective radius of the cavity 60, so that the input port 92 has predominantly an angular (as opposed to a radial) dimension, and can be spaced apart from the longitudinal axis 64 by a radial distance again as discussed in relation to the transverse angular irises 88. Thus, in some configurations of the resonator assembly 50, the centre point of the input port 92 can have a radial spacing of about 0.455R, where R is the effective radius of the cavity 60. But other radial spacings within the ranges discussed above may be suitable as well for different applications.

[0043] Now referring specifically to FIG. 7B, input coupling can alternatively be achieved using an input port 94 formed in the end wall 56 at a location having an angular position, in relation to the second characterizing vector 76, equal to an integer multiple of 90 degrees. The input port 94 is formed out of an elongated iris oriented in a generally radial direction and spaced apart from the longitudinal axis 64 by a radial distance, depending on the particular application, falling within one of the ranges discussed above in the context of the radial iris 84. In one exemplary configuration, the centre point of the input port 94 can have a radial spacing of about 0.728R, where R is the effective radius of the cavity 60.

[0044] Referring now to FIGS. 8A and 8B, one or more tuning elements can be placed within the cavity 60 at different locations in order to make minor adjustments to the resonant frequencies of one or the other of the TE_{22N} modes 70 and 72, or in some cases to both TE_{22N} 70 and 72 modes simultaneously. As will be appreciated, the number and location of tuning elements is optimizable and may depend on the particular application or use of the microwave resonator assembly 50. At least some of the tuning elements shown in FIGS. 8A and 8B can also improve the spurious performance of the microwave resonator assembly 50, as will be explained. The tuning elements can be formed using screws or other suitable structures (e.g., rods, wall deformations and dielectric blocks) for causing small perturbations to the electromagnetic field patterns of the TE_{22N} modes 70 and 72. For the sake of clarity only, reference may be made primarily to tuning screws.

[0045] To provide relatively independent tuning of the orthogonal TE_{22N} modes 70 and 72, at least some of the tuning elements can be placed at locations within the cavity 60 where one of the TE_{22N} modes 70 and 72 has relatively large field components as compared to the other TE_{22N} mode, so that the tuning element disproportionately disturbs one of the corresponding field patterns relative to the other. As will be appreciated, the small field perturbation can incrementally adjust the corresponding TE_{22N} mode's resonant frequency higher or lower, thereby "tuning" the corresponding TE_{22N} mode to a selected frequency (for example, in order to place the centre frequency of a microwave bandpass filter). Although tuning elements, such as tuning screws, may be utilized to incur fine adjustments to a resonant frequency, there may be a practical limit on the degree to which that resonant frequency can be adjusted. For coarser adjustments, it may be required or preferable to re-design other dimensions of the cavity 60, such as its axial length or effective radius 62.

[0046] The tuning elements shown specifically in FIG. 8A are suitable for tuning the first TE_{22N} mode 70 defined by characterizing vector 74. Tuning screws 82 may project through the side wall 54 into the interior of cavity 60, at a suitable axial height (which may depend on the value of "N") within the cavity 60, and at angular positions equal to an integer multiple of 90 degrees in relation to the second characterizing vector 76. The dimensions and penetration depth of the tuning screw 82 into the cavity 60 determine its influence on the resonant frequency of the first TE_{22N} mode 70.

[0047] Alternatively, or additionally, one or more tuning screws 95 may be included in the resonator assembly 50. The tuning screws 95 project through the end wall 56 into the interior of the cavity 60, and are placed at locations having angular positions equal to an integer multiple of 90 degrees in relation to the first characterizing vector 74. The tuning screws 95 can also each be spaced from the longitudinal axis 64 of the cavity 60 by a radial distance of about 0.455R, where R is the effective radius of the cavity 60, or in one of the indicated ranges for the transverse angular iris 88. As discussed above, within these approximate ranges and at the angular positions shown, the field components of the first TE_{22N} mode 70 are relatively dense.

[0048] As a further possibility, one or more tuning screws 96 may project through the end wall 56 into the interior of the cavity 60, at angular positions equal to an integer multiple of 90 degrees in relation to the second characterizing vector 76. The tuning screws 96 can also each be spaced from the longitudinal axis 64 of the cavity 60 by a radial distance of between about 0.728R or one of the above-discussed ranges for the radial iris 84, as the field components of the first TE_{22N} mode 70 are again relatively dense in these regions of the cavity 60.

[0049] Similar tuning elements are illustrated in FIG. 8B, but at locations within the cavity 60 that are suitable for tuning the second TE_{22N} mode 72. Accordingly, tuning screws 80 project into the interior of the cavity 60 (at a suitable axial height based on the value of "N"), and at angular positions equal to an integer multiple of 90 degrees in relation to the first characterizing vector 74. Tuning screws 98 project through the end wall 56, spaced apart from each other by 90-degrees, at angular positions within the cavity 60 equal to an integer multiple of 90-degrees in relation to the second characterizing vector 76. Finally, tuning screws 99 project through the end wall 56 or 58, spaced apart 90-degrees from each other, at angular positions equal to an integer multiple of 90-degrees in relation to the first characterizing vector 74. The tuning screws 98 and 99 can have the same radial spacing (or range of spacing) as tuning screws 95 and 96, respectively, shown in FIG. 8A.

[0050] A single tuning screw 97, projecting into the interior of the cavity 60 at the centre-point of the end wall 56 or 58, aligned with the longitudinal axis 64, can also be included in the microwave resonator assembly 50. Owing to the radial symmetry of the cavity 60, the tuning screw 97 can be used to adjust the resonant frequencies of both the TE_{22N} modes 70 and 72 simultaneously, with the amount and direction (higher or lower) of the adjustment depending on the dimensions and penetration depth into the cavity 60 of the tuning screw 97. Inclusion of the tuning screw 97 can additionally improve the spurious performance of the microwave resonator assembly 50 by pushing the resonant frequencies of adjacent, spurious modes away from the operational dual TE_{22N} mode. Because the field components of each TE_{22N} mode 70 and 72 are fairly small at the centre-point of the end wall 56 or 58 (see FIG. 2), tuning screw 97 will have a larger relative sifting of the resonant frequencies of other resonant modes having comparatively large field components at this point. For example, the TM_{121} spurious mode is strong at the centre-point and therefore will be disproportionately affected. Tuning screw 97 can be included, for example, to supplement to the other tuning elements illustrated in FIGS. 8A and 8B and for improved spurious performance.

[0051] Referring now to FIGS. 9A-9C, there is illustrated a microwave resonator filter 100 in perspective, top and side views. The microwave resonator filter 100 is realized using microwave resonator assembly 50, shown in FIGS. 1A and 1B, to form a multi-cavity structure. By exciting each cavity in the dual TE_{22N} mode, the microwave resonator filter 100 realizes 2 poles per cavity for an overall 4-pole filter characteristic. Of course, it should be appreciated that the microwave resonator filter 100 can be realized using any arbitrary number of cavities, in alternative configurations, to realize additional poles and higher order filters. However many cavities are included, a combination of direct and cross-coupling between adjacent cavities makes it possible to realize elliptic and Chebyshev functions. Transmission zeros are also realizable by designing the filter to incorporate negative mode coupling, either between orthogonal modes excited within a single cavity or between mutually aligned modes resonating in adjacent filter cavities. For brevity some aspects of the microwave resonator filter 100 described above in the context of the resonator assembly 50 will not be described again or may be described in less detail.

[0052] A first cylindrical enclosure 52a defining a first cavity 60a is formed out of cylindrical sidewall 54a, end wall 56a and common end wall 158. A second cylindrical enclosure 52b defining a second cavity 60b is formed out of cylindrical sidewall 54b, end wall 56b and the common end wall 158. Accordingly, the first cavity 60a is separated from the second cavity 60b by the common end wall 158 between the first and second cylindrical enclosures 52a and 52b, so that the first and second cavities 60a and

60b are adjacent and collinear (i.e., so that the first and second cavities 60a and 60b share a common longitudinal axis 64). While the cavities 60a and 60b are illustrated in FIGS. 9A-9C as sharing a common end wall 158 between the cylindrical enclosures 52a and 52, alternatively, the cavities 60a and 60b can be separated by corresponding adjacent end walls having a small air gap formed therebetween.

[0053] Input port 66a coupled to external waveguide section 68a excites a first TE_{22N} mode 70 within cavity 60a having a first polarization, as described above, defined by the first characterizing vector 74. The pair of diametrically opposed coupling screws 78a projecting through the sidewall 54a into the interior of the cavity 60a couple the first TE_{22N} mode 70 excited in the first cavity 60a with a second TE_{22N} mode 72 also excited in the first cavity 60a, the second TE_{22N} mode 72 having an orthogonal polarization relative to the first TE_{22N} mode 70. Tuning screws 82a and 80a optionally adjust the resonant frequencies of the first and second TE_{22N} modes 70 and 72 for closer placement to a selected centre frequency of the microwave resonator filter 100.

[0054] Transverse angular iris 90 formed in the common end wall 158 between the first and second cavities 60a and 60b couples the second TE_{22N} mode 72 excited in the first cavity 60a with a third TE_{22N} mode 72 excited in the second cavity 60b. Simultaneously, radial iris 84 formed in the common end wall 158 couples the first TE_{22N} mode 70 excited in the first cavity 60a with a fourth TE_{22N} mode 70 excited in the second cavity 60b. The first and fourth TE_{22N} modes have mutually aligned polarizations defined by the characterizing vector 74, while the second and third TE_{22N} modes have mutually aligned polarizations defined by the characterizing vector 76.

[0055] Within the second cavity 60b, the pair of diametrically opposed coupling screws 79b projecting through the sidewall 54b couple together the third TE_{22N} mode 72 and fourth TE_{22N} mode 70 excited also in the second cavity 60b. As will be explained in more detail below, the angular position of the coupling screws 79b offset 45-degrees in relation to the coupling screws 79a placed in the first cavity 60a realizes transmission zeroes in the microwave resonator filter 100. Also, output port 66b is used to radiate electromagnetic energy out of the second cavity 60b by coupling the fourth TE_{22N} mode 70 within the second cavity 60b with the external waveguide section 68b. As in a symmetric filter, the designation of "input" and "output" ports may be somewhat arbitrary and depend on perspective, the output port 66b is substantially similar to the input port 66a and can be formed in any of the locations illustrated in FIG. 3 (or alternatively FIGS. 7A-7B).

[0056] The particular combination of direct and cross-coupling elements shown in FIGS. 9A-9C realizes a 4-pole, cross-coupled filter. A general folded path between the input port 66a and output port 66b is formed by the successive mode coupling provided by the coupling screws 78a (first to second), the transverse angular iris 90 (second to third), and the coupling screws 79b (third to fourth). In addition to the general folded path, the radial iris 84 then provides a cross-coupled path directly between the first TE_{22N} mode 70 resonating in the first cavity 60a and the mutually aligned fourth TE_{22N} mode 70 resonating in the second cavity 60b. Accordingly, in the configuration shown, the transverse angular iris 90 serves as a direct coupling element, while the radial iris 84 serves as a cross-coupling element. Although it should be appreciated that the function served by these coupling elements may be reversed and depends on their angular position in relation to the characterizing vectors 74 and 76, as herein described. Moreover, the term "direct coupling element" as used herein can refer to any element that provides coupling between two successive modes in the general folded path (e.g., second and third), while the term "cross coupling element" can refer to any element that provides coupling between two non-successive (e.g., first and fourth) modes in the general folded path.

[0057] It should also be appreciated that, as an alternative to the cross-coupled filter configuration shown in FIGS. 9A-9C, a general folded filter configuration (without cross-coupling) is also realizable by omitting the cross-coupling element, in this case the radial iris 84. With no cross-coupled path directly between the first and fourth TE_{22N} modes 70, the remaining coupling elements (i.e., coupling screws 78a, transverse angular iris 90, and coupling screws 79b) realize the general folded path between the input port 66a and output port 66b by coupling the first, second, third and fourth modes successively.

[0058] Principles of microwave filter design may be utilized in order to determine the number, type, location and size of the coupling elements included in the microwave filter 100. For example, a transfer function for the microwave filter 100 can be calculated, usually by selecting a filter type (elliptic, Chebyshev, etc.), and then calculating poles and zeros of the transfer function that will realize a specified set of performance criteria, such as insertion loss, return loss, passband ripple, stopband ripple, bandwidth, isolation. Often the specified performance criteria will be interrelated to the order of the microwave filter 100, so that either the selected criteria will dictate a minimum required filter order or, alternatively, if the filter order (e.g., 4-poles, 8-poles, etc.) is fixed, constraints may then be imposed on the realizable performance criteria. As will be appreciated, the design process can be iterative requiring multiple formulations until an acceptable transfer function is designed. Design software may be of assistance throughout the process.

[0059] After synthesizing the filter transfer function, a variety of different techniques can then be used to realize a physical microwave resonator (e.g., microwave resonator filter 100) that exhibits the synthesized transfer characteristics. One such technique involves formulating a coupling matrix (usually designated "M") from the synthesized transfer function. As will be appreciated, the entries in the coupling matrix M specify the magnitude and sign of coupling required between each resonator included in the microwave resonator filter 100 to realize the synthesized transfer function. Once the coupling matrix has been formulated, physical dimensions for the microwave filter can be solved that provide the required couplings. Of course, it is possible that not every synthesized transfer function will be physically realizable. For example, cross-coupling between two non-successive resonators (or even between successive resonators) may be required that cannot easily be realized. The physical realization stage of the design process may be iterative as well, and it may be necessary to reformulate the filter transfer function subject to physical constraints as well as performance criteria.

[0060] Assuming a realizable transfer function has been synthesized, the coupling elements included in the microwave resonator filter 100 can be selected and configured to meet the requirements of the coupling matrix M. In terms of coupling the first TE_{22N} mode 70 and second TE_{22N} mode 72 excited in the first cavity 60a, the number and respective sizing of coupling screws 78a (as well as angular position) can be varied to meet the requirement. Similarly, in terms of coupling the third TE_{22N} mode 72 and fourth TE_{22N} mode 70 excited in the second cavity 60b, the number and respective sizing of coupling screws 79b (as well as angular position) can be varied to meet the requirement. In general, increasing the size and number of coupling elements will increase the amount of coupling provided. Depending on whether transmission zeros are to be created, coupling screws having the same or different polarity of coupling can be used in the cavities 60a and 60b. In the exemplary configuration shown, the coupling screws have opposite polarities to create transmission zeros.

[0061] A similar process can be followed to size the coupling elements formed in the common end wall 158 for radiating energy between the two cavities 60a and 60b. The number and relative sizing of radial irises 86 and/or transverse angular irises 90 (FIG. 5B) can be varied until the required coupling between the mutually aligned second and third TE_{22N} modes 72 excited in the first and second cavities 60a and 60b, respectively, is achieved. If cross-coupling between the first and fourth TE_{22N} modes 70 is also prescribed by the coupling matrix M, then the number and relative sizing of radial irises 84 and/or transverse angular irises 88 (FIG. 5A) can be varied until the required coupling is realized. The illustrative combinations presented in FIG. 6 represent just some of the possible ways in which to realize different amounts and direct and cross-coupling of modes in the microwave resonator filter 100. Design software can again be of assistance in the process of sizing the different coupling elements.

[0062] Referring back to FIGS. 4A and 4B, the microwave resonator filter 100 is configurable based on the selection of intra or inter cavity coupling elements to realize two transmission zeros, thereby creating an overall symmetric filter function. Coupling of the first TE_{22N} mode 70 to the second TE_{22N} mode 72 within cavity 60a is achieved using one or more of the coupling screws 78, while coupling of the third TE_{22N} mode 72 to the fourth TE_{22N} mode 70 within cavity 60b is achieved using one or more of the coupling screws 79, which are 45-degrees offset from the coupling screws 78. When coupling screws 78 are included in cavity 60a and coupling screws 79 are included in cavity 60b (or vice versa), the respective couplings in each cavity 60a and 60b have opposite polarities, or are disposed in an anti-symmetrical relationship in relation to each other, resulting in the creation of the transmission zeros. On the other hand, transmission zeros can be avoided by placing coupling screws 78 (or equivalently coupling screws 79) in each cavity 60a and 60b, so that the respective couplings have the same polarity (whether positive or negative) and therefore do not form an anti-symmetrical relationship.

[0063] Referring now to FIGS. 10A and 10B, in an alternate configuration of the resonator assembly 50, coupling elements are formed in the sidewall 54 of the cylindrical enclosure 52 (as opposed to the end wall 58) to make the microwave resonator assembly 50 suitable for inclusion in a planar-mounted microwave filter. The configuration of microwave resonator assembly 50 shown in FIGS. 10A and 10B is similar in some respects to that shown in FIG. 1A and 1B. For the sake of clarity, discussion of like or analogous elements may be somewhat abbreviated while differences may be emphasized.

[0064] A cavity 60 is again defined by a cylindrical enclosure 52 formed out of sidewall 54 extending between opposing end walls 56 and 58. Input port 66 couples electromagnetic energy radiated by external waveguide section 68 into the cavity 60, inside which a first TE_{22N} mode 70 having a first polarization (defined by characterizing vector 74) is excited. At least one discontinuity is formed within the cavity 60, for example using coupling screws 78 or 79, to couple the first TE_{22N} mode 70 with a second TE_{22N} mode 72 having a second field polarization orthogonal to that of the first TE_{22N} mode 70. Tuning screw 82 is used to make small adjustments to the resonant frequency of the first TE_{22N} mode 70; tuning screw 80 serves the same function for the second TE_{22N} mode 72.

[0065] However, rather than forming coupling elements in the end wall 58 for radiating electromagnetic energy out of the cavity 60 (e.g., into an adjacent cavity for realizing a multi-cavity microwave filter), coupling elements are instead formed in the sidewall 54. As illustrated in FIGS. 10A and 10B, when located at angular positions within the cavity 60 equal to an integer multiple of 90-degrees in relation to the second characterizing vector 76, longitudinal iris 83 couples the first TE_{22N} mode 70 predominantly while coupling the second TE_{22N} mode 72 to a comparatively less degree. In this respect, the longitudinal iris is similar to the radial iris 84 (FIG. 5A). Once the input port 66 fixes the polarization of the first TE_{22N} mode 70, any of four equivalent locations in the sidewall 54, spaced 90-degrees apart from each other, can be used to radiate the first TE_{22N} mode 70 out of the cavity 60 using the longitudinal iris 83.

[0066] Transverse angular iris 85 is shown in FIGS. 10A and 10B formed in the side wall 54 in close proximity to, and at the same angular position as, the longitudinal iris 83. At that angular position within the cavity 60, transverse angular iris 85 couples the second TE_{22N} mode 72 predominantly while coupling the first TE_{22N} mode 70 to a comparatively less degree. But again owing to the 90-degree radial symmetry of the cavity 90, the angular position of the transverse angular iris 85 is not fixed and can equal any integer multiple of 90-degrees in relation to the second characterizing vector 76. In this regard, the transverse angular iris 85 is similar to the transverse angular iris 90 (FIG. 5B). While it is not strictly necessary for the longitudinal iris 83 to have the same angular position as the transverse angular iris 85 within the cavity 60, locating these two coupling elements at the same angular position (as will be seen) can facilitate design of a two-cavity, planar mounted microwave filter. Of course, if three or more cavities are included in the microwave filter, then other relative angular positions for the longitudinal iris 83 and transverse angular iris 85 may be apparent.

[0067] Referring now to FIGS. 11A and 11B, in yet another alternate configuration of the microwave resonator assembly 50, the transverse angular iris 85 shown in FIGS. 10A and 10B can be replaced with a second longitudinal iris 87 located at a 45-degree angular offset, in relation to the longitudinal iris 83, plus in some cases an integer multiple of 90 degrees. Accordingly, similar to the radial iris 86 (FIG. 5B), the longitudinal iris 87 can be located within the cavity 60 at an angular position equal to an integer multiple of 90-degrees in relation to the first characterizing vector 74. Any of the four locations within the cavity 60 satisfying this relationship will provide good coupling of the second TE_{22N} mode 72. Although as will be seen, preserving a 45-degree angular between the longitudinal irises 83 and 87 can facilitate design of a two-cavity, planar mounted microwave filter.

[0068] Referring now to FIGS. 12A and 12B, there is illustrated a microwave resonator filter 200 in perspective and top views. The microwave resonator filter 200 is realized using the microwave resonator assembly 50, shown in FIGS. 10A-B, which through inclusion of sidewall coupling elements is suitable for constructing a planar-mounted, microwave filter. Again by operating in the dual TE_{22N} mode, the microwave resonator filter 200 realizes 2 poles in each of two adjacent cavities for an overall 4-pole bandpass characteristic. Of course, additional cavities can be included to realize additional poles in the filter function. A combination of direct and cross-coupling of modes resonating in adjacent cavities makes it possible to realize a variety of different linear filter functions, such as elliptic and Chebyshev filter functions, as well as other functions. Transmission zeros are also realizable through the use of negative mode coupling. For the sake of clarity, discussion of certain aspects shared in common by the two microwave resonator filters 100 and 200 may be abbreviated while differences may be highlighted.

[0069] A first cavity 60a is formed in close lateral proximity to a second cavity 60b, so that corresponding adjacent portions of the cylindrical sidewalls 54a and 54b separate the two cavities 60a and 60b. In some cases, a small arcuate portion of the cylindrical sidewalls 54a and 54b can be shared between the first and second cavities 60a and 60b to form a common sidewall portion (not shown). However, a small air gap can alternatively be formed between the corresponding adjacent portions of sidewalls 54a and 54b, provided the inter-cavity separation is relatively short (e.g., to maintain good coupling between the two cavities 60a and 60b). In this arrangement, the first and second cavities 60a and 60b have respective longitudinal axes (not explicitly shown) that are parallel, but non-collinear.

[0070] Input port 66a coupled to external waveguide section 68a excites a first TE_{22N} mode 70 within cavity 60a having a first polarization defined by the first characterizing vector 74. The pair of diametrically opposed coupling screws 78a projecting through the sidewall 54a couple the first TE_{22N} mode 70 excited in the first cavity 60a with a second TE_{22N} mode 72 excited in cavity 60a and having an orthogonal field polarization relative to the first TE_{22N} mode 70. Tuning screws 82a and 95a are optionally included to adjust the resonant frequency of the first TE_{22N} mode 70 to a selected centre frequency of the microwave resonator filter 200. Likewise tuning screws 80a and 98a are optionally included adjust the resonant frequency of the second TE_{22N} mode 72 also to the selected centre frequency.

[0071] As shown in FIGS. 12A and 12B, transverse angular iris 85 couples the second TE_{22N} mode 72 excited in the first cavity 60a with a mutually aligned third TE_{22N} mode 72 excited in the second cavity 60b. Simultaneously, longitudinal iris 83 couples the first TE_{22N} mode 70 excited in the first cavity 60a with a mutually aligned fourth TE_{22N} mode 70 excited in the second cavity 60b. Coupling screw 79b then couples together the third TE_{22N} mode 72 and fourth TE_{22N} mode 70 excited in the second cavity 60b, and output port 66b is used to radiate electromagnetic energy out of the second cavity 60b by coupling the fourth TE_{22N} mode 70 with the external waveguide section 68b. Tuning screws 80b and 98b are optionally included to adjust the resonant frequency of the third TE_{22N} mode 72 to the selected centre frequency of the microwave resonator filter 200, as are tuning screws 82b and 95b for the same purpose in relation to the fourth TE_{22N} mode 70. Screws 97a and 97b are optionally included to improve the spurious free range of the microwave resonator filter 200.

[0072] The respective dimensions and axial positioning of the longitudinal iris 83 and the transverse angular iris 85 are optimizable to adjust the coupling provided by each iris as specified in the coupling matrix M. For example, the longitudinal axis 83 can be located at or near a maximum in the axial field pattern of the TE_{22N} mode (i.e., at an odd multiple of quarter-wavelengths in the axial direction) to provide strong coupling of the first and fourth TE_{22N} modes 70, but also at other axial positions depending on the application. The transverse angular iris 85 can then be located vertically adjacent the longitudinal axis 83 in space remaining in the sidewall 54. As shown in FIG. 12B, the transverse angular iris 85 abuts the end wall 58, but other locations are possible as well.

[0073] Referring now to FIGS. 13A and 13B, the respective couplings of the longitudinal iris 83 and transverse angular iris 85 are related to their angular position within the cavity 60a (or equivalently within the cavity 60b). For example, by undergoing a 45-degree translation relative to the configuration seen in FIGS. 12A and 12B, the longitudinal iris 87 now couples the second and third TE_{22N} modes 72, while the transverse angular iris 89 couples the first and fourth TE_{22N} modes 70. intermediate angles between these two extremes are possible as well, in which case the inter-cavity coupling elements would be offset an integer multiple of 90-degrees from some intermediate vectors between the first or second characterizing vectors 74 and 76. At this intermediate angle, each of the longitudinal iris 87 and the transverse angular iris 89 would provide some non-negligible coupling of the first and fourth TE_{22N} modes 70, as well as some non-negligible coupling of the second and third TE_{22N} modes 72. It should be understood, however, that the angle between the longitudinal iris 87 and the transverse angular iris 89 can remain 45-degrees. Depending on the particular application, any offset angle in relation to the characterizing vectors 74 and 76 may be prescribed. Accordingly, the relative spacing and angular positions of these coupling elements are optimizable to realize different filter functions in the microwave resonator filter 200.

[0074] Referring now to FIGS. 14A and 14B, in an alternative configuration of the microwave resonator filter 200, a pair of longitudinal irises 83 and 87 is used to couple the first and second cavities 60a and 60b. The resonant modes coupled by each longitudinal iris 83 or 87 (as well as the relative strengths of these couplings) are related to the angular position of the respective coupling element within the cavities 60a and 60b. The longitudinal iris 83, being diametrically opposed to the input port 66a (and hence an integer multiple of 90-degrees offset from the second characterizing vector 76), predominantly but not exclusively couples the first and fourth TE_{22N} modes 70. Likewise the longitudinal axis 87, being 45-degrees offset from the longitudinal axis 83 (and hence an integer multiple of 90-degrees offset from the first characterizing vector 74), predominantly but not exclusively couples the second and third TE_{22N} modes 72.

[0075] Although not explicitly illustrated, the relative couplings provided by the longitudinal irises 83 and 87 would be opposite to that provided by the exemplary configuration shown in FIGS. 14A and 14B. If the longitudinal axis 87 were instead to be located diametrically opposed to the input port 66a, then it would be the longitudinal iris 87 coupling the first and fourth TE_{22N} modes 70 and the longitudinal iris 83 coupling the second and third TE_{22N} modes 72. Again the longitudinal irises 83 and 87 can be formed at angular positions equal to an integer multiple of 90-degrees offset from some intermediate vectors between the first and second characterizing vectors 74 and 76, thereby adjusting the relative couplings of each orthogonal mode to suit the application.

[0076] Some combinations of the longitudinal iris 83 with the longitudinal iris 87 will also realize transmission zeros in the filter characteristic of the microwave resonator filter 200. The polarity of the coupling provided by the longitudinal irises 83 and 87 can depend on the size of the iris in relation to the free-space wavelength of the resonance modes being coupled together. For example, if the major dimension (i.e., axial length) of the longitudinal iris 83 or 87 is less than one half of the free-space wavelength, the resulting coupling will have a certain polarity. But coupling of the opposite polarity will result if the major dimension of the longitudinal iris 83 or 87 is greater than one half of the free-space wavelength. By sizing the axial lengths of the longitudinal irises 83 and 87 in relation to one half-wavelength, the couplings provided by each respective iris 83 and 87 can be made to have opposite polarities and relative magnitudes, as specified by the M matrix, such that transmission zeros are created. For example, the length of one longitudinal iris (e.g., 83) can be less than one half-wavelength, while the length of the other longitudinal iris (e.g., 87) can be larger than one half-wavelength. By adjusting the relative dimensions of the two longitudinal irises 83 and 87, depending on the application, to provide the specified couplings, the transmission zeros can be realized.

[0077] In an alternative configuration of the resonator assembly 50 not explicitly illustrated, the longitudinal irises 83 and 87 can be sized to be both smaller or both larger than one half of the free-space wavelength. In either case, both smaller or both larger, the relative couplings provided by the longitudinal irises 83 and 87 will have the same polarity, positive or negative. It is not necessary for the longitudinal irises to have the same axial length and can be sized differently, depending on the particular application, to provide different relative couplings. In these configurations, transmission zeros can be created in the microwave filter 200 instead by the relative angular positions of the coupling screws 78 and 79 placed in each cavity 60a and 60b, as described above with reference to FIGS. 4A and 4B.

[0078] Referring now to FIGS. 15A and 15B, in an alternative configuration of the microwave resonator filter 200, a single longitudinal iris 83 is used to provide resonant mode coupling between the first and second cavities 60a and 60b. Coupling screw 91a placed in cavity 60a provides coupling between the first TE_{22N} mode 70 and second TE_{22N} mode 72 resonating therewithin. Similarly coupling screw 91 b placed in cavity 60b provides coupling between the third TE_{22N} mode 72 and fourth TE_{22N} mode 70. The coupling screws 91a and 91b project through cavity end walls (as opposed to a side wall) at angular positions located substantially intermediate the characterizing vectors 74 and 76, where the TE_{22N} modes 70 and 72 have non-zero field components.

[0079] As discussed above, the single longitudinal iris 83 may provide coupling of the first and fourth TE_{22N} modes 70 simultaneously with coupling of the second and third TE_{22N} modes 72. However, the relative amounts of each type of mode coupling may generally depend on the angular position of the longitudinal iris 83 in relation to the characterizing vectors 74 and 76. At the angular position shown explicitly in FIGS. 15A and 15B, the longitudinal iris 83 (being offset an integer number of 90 degrees from the second characterizing vector 76) may predominantly couple the first and fourth TE_{22N} modes 70. However, some amount of coupling of the second and third TE_{22N} modes 72 excited in the cavities 60a and 60b will occur as well.

[0080] The sizing and axial positioning of the longitudinal iris 83 are again two of the free variables through which to control the amount of coupling provided to suit the particular application. However, as there is only the one longitudinal iris 83 used to couple each pair of mutually aligned TE_{22N} modes, the realizable couplings may be somewhat constrained as compared to a filter configuration that utilizes two or more coupling elements. As will be appreciated, the inclusion of additional coupling elements increases the number of free variables, such as relative angular spacing and sizing, which can be optimized in the design process. As a third possible design variable, the angular position of the longitudinal iris 83 in relation to the characterizing vectors 74 and 76 can also be optimized. Thus, although not explicitly shown, the longitudinal iris 83 can also be translated 45-degrees to be offset an integer number of 90 degrees from the first characterizing vector 76. At this alternative angular position, the longitudinal iris 83 then predominantly couples the second and third TE_{22N} modes 72. For intermediate couplings, some angular offset between this and the position shown in FIGS. 15A and 15B can be selected.

[0081] Referring now to FIGS. 16A and 16B, there is illustrated a microwave resonator filter 300 in perspective and top views. The microwave resonator filter 300 is formed using a single microwave resonator assembly 50 and, by operating in the dual TE_{22N} mode, realizes a 2-pole bandpass characteristic. In the configuration shown, input port 66a and output port 66b are provided in a single cavity 60 and lead to external waveguide sections 68a and 68b, respective. The input port 66a excites the first TE_{22N} mode 70 within cavity 60 and the output port 66b, being located 45-degrees offset from the input port 66a, is suitable for coupling the second TE_{22N} mode 72. Coupling between the orthogonal TE_{22N} modes 70 and 72 is provided, for example, using coupling screw 91. It should be appreciated however that one or more coupling screws 78 or 79 could be used alternatively or additionally. Tuning screws 95 and 98 are included and used to make small adjustments to the resonant frequencies of the first and second TE_{22N} modes 70 and 72, respectively.

[0082] Referring now to FIGS. 17A-D, alternative cavity geometries can be utilized in the resonator assembly 50 to adjust one or more performance characteristics. Each of the alternative geometries illustrated presents different boundary fields for the TE_{22N} mode, relative to the cylindrical shape of the cavity 60. For example, in FIG. 17A, the cavity 160 comprises a central cylindrical section 161 between two inwardly tapered end sections 163. The cavity 260 shown in FIG. 17B similarly comprises a central cylindrical section 261, but now includes two outwardly tapered end sections 263. Alternatively, as seen in FIG. 17C, the cavity 360 can comprise central cylindrical 361 between two puck sections 363. Finally, the cavity 460 shown in FIG. 17D includes central cylindrical section 461 between two end flange sections 463.

[0083] Two of the performance characteristics that can be varied in the alternative cavity geometries are spurious performance and Q factor. For example, the outwardly tapering end sections 263 in FIG. 17B and the end flange sections 463 in FIG. 17D, which each represent an expansion of the corresponding cavity relative to its axial midsection, can offer better spurious performance on the low-frequency side of the passband. On the other hand, the inwardly tapering end sections 163 in FIG. 17A and the puck sections 363 in FIG. 17C, which each represent a narrowing of the corresponding cavity relative to its axial midsection, can offer better spurious performance on the high-frequency side of the passband. The inwardly tapering end sections 163 and the puck sections 363 also provide a larger Q factor relative to the cylindrical cavity 60.

[0084] White the above description provides examples and specific details of various embodiments, it will be appreciated that some of the described features and/or functions admit to modification without departing from the scope of the described embodiments. The detailed description of embodiments presented herein is intended to be illustrative of the invention, the scope of which is limited only by the language of the claims appended hereto.

Claims

1. A microwave resonator assembly (50) comprising:

   a cavity (60) defined by an electrically conductive cylindrical enclosure (52) **characterized in that** electromagnetic energy radiated into the cavity (60) resonates in a plurality of resonance modes comprising a dual TE_{22N} mode, N greater than or equal to one;
   an input port (66) provided in the cylindrical enclosure for radiating a first TE_{22N} mode (70) having a first polarization into the cavity (60); and
   a discontinuity formed within the cavity (60) con-

figured to electromagnetically couple the first TE_{22N} mode (70) with a second TE_{22N} (72) mode having a second polarization orthogonal to the first polarization.

2. The microwave resonator assembly (50) of claim 1, wherein
a field pattern of the first TE_{22N} mode (70) defines a first characterizing vector (74) projecting radially in relation to a longitudinal axis (64) of the cavity (60), the first characterizing vector (74) corresponding to where the field pattern of the first TE_{22N} mode (70) has a maximum radial component and a minimum angular component;
a field pattern of the second TE_{22N} mode (72) defines a second characterizing vector (76) projecting radially in relation to the longitudinal axis (64) and forming a 45 degree angle with the first characterizing vector (74), the second characterizing vector (76) corresponding to where the field pattern of the second TE_{22N} mode (72) has a maximum radial component and a minimum angular component; and
the discontinuity is formed at a location within the cavity (60) having an angular position intermediate the first and second characterizing vectors (74, 76), where the first and second TE_{22N} modes (70, 72) each have non-zero field components.

3. The microwave resonator assembly (50) of claim 2, wherein the angular position of the discontinuity is an angular midpoint between the first and second characterizing vectors (74, 76).

4. The microwave resonator assembly (50) of claim 3, wherein the input port (66) has an angular position in relation to the second characterizing vector (76) equal to an integer multiple of 90 degrees.

5. The microwave resonator assembly (50) of any of claims 2, 3 or 4, further comprising a plurality of discontinuities formed within the cavity (60) for electromagnetically coupling the first TE_{22N} mode (70) with the second TE_{22N} mode (72), each discontinuity formed at a corresponding location within the cavity having an angular position in relation to the first or second characterizing vector (74, 76) equal to 22.5 degrees plus an integer multiple of 90 degrees, where the first and second TE_{22N} modes (70, 72) each have non-zero field components.

6. The microwave resonator assembly (50) of claim 2, further comprising a plurality of discontinuities formed within the cavity (60) for adjusting a resonant frequency of the first TE_{22N} mode (70) or the second TE_{22N} mode (72), each discontinuity formed at a corresponding location within the cavity (60) having an angular position in relation to either the first or second characterizing vector (74, 76) equal to an integer multiple of 90 degrees, where one of the first and second TE_{22N} modes (70, 72) has field components substantially larger than the other of the first and second TE_{22N} modes (70, 72).

7. The microwave resonator assembly (50) of any of claims 2 to 6, further comprising
at least one direct coupling element provided in the cylindrical enclosure (52) for radiating the second TE_{22N} mode (72) out of the cavity; and
at least one cross coupling element provided in the cylindrical enclosure (52) for radiating the first TE_{22N} mode (70) out of the cavity.

8. A microwave resonator filter (100) realized using a plurality of microwave resonator assemblies (50), the resonator filter (100) comprising:

a plurality of cavities including at least a first cavity (60a) and a second cavity (60b) located adjacent to the first cavity (60a), each of the first cavity (60a) and the second cavity (60b) defined by a corresponding electrically conductive cylindrical enclosure (52a, 52b) **characterized in that** electromagnetic energy radiated into that cavity resonates in a plurality of resonance modes comprising a dual TE_{22N} mode, N greater than or equal to one; and
at least one coupling element for radiating electromagnetic energy between the first cavity (60a) and the second cavity (60b), the at least one coupling element configured to electromagnetically couple a first TE_{22N} mode (70) resonating in the first cavity with a fourth TE_{22N} mode (70) resonating in the second cavity, and a second TE_{22N} mode (72) resonating in the first cavity (60a) with a third TE_{22N} mode (72) resonating in the second cavity (60b), the first and fourth TE_{22N} modes (70) having a first polarization and the second and third TE_{22N} modes (72) having a second polarization orthogonal to the first polarization.

9. The microwave resonator filter (100) of claim 8, wherein
the first TE_{22N} mode (70) defines a first characterizing vector (74) projecting radially in relation to a longitudinal axis (64) of the first cavity, the first characterizing vector (74) corresponding to where the first TE_{22N} (70) mode has a maximum radial component and a zero angular component;
the second TE_{22N} mode (72) defines a second characterizing vector (76) projecting radially in relation to the longitudinal axis (64) and forming a 45 degree angle with the first characterizing vector (74), the second characterizing vector (76) corresponding to where the second TE_{22N} (72) mode has a maximum radial component and a zero angular component;

and
the at least one coupling element comprises at least one direct coupling element for electromagnetically coupling the second TE_{22N} mode (72) with the third TE_{22N} mode (72), the at least one direct coupling element having an angular position in relation to either the first or second characterising vector (74. 76) equal to an integer multiple of 90 degrees.

10. The microwave resonator filter (100) of claim 9, wherein
the first and second cavities (60a, 60b) are collinear;
the at least one coupling element is formed in a common end wall (158) separating the first and second cavities (60a, 60b); and
the at least one direct coupling element comprises
a transverse angular iris (90), being transverse to the radius of the cavity (60) and having an angular position in relation to the second characterizing vector (76) equal to an integer multiple of 90 degrees, and/or
a radial iris (86) having an angular position in relation to the first characterizing vector (74) equal to an integer multiple of 90 degrees.

11. The microwave resonator filter (100) of claim 9, wherein
the first and second cavities (60a, 60b) are non-collinear;
the at least one coupling element is formed between adjacent sidewall portions (54) of the first and second cavities (60a, 60b); and
the at least one direct coupling element comprises
a transverse angular iris (85), being transverse to the radius of the cavity (60) and having an angular position in relation to the second characterizing vector (76) equal to an integer multiple of 90 degrees, and/or
a longitudinal iris (83), being parallel to the longitudinal axis (64) of the cavity (60) and having an angular position in relation to the first characterizing vector (74) equal to an integer multiple of 90 degrees.

12. The microwave resonator filter (100) of claim 9, wherein the at least one coupling element further comprises at least one cross coupling element for electromagnetically coupling the first TE_{22N} mode (70) with the fourth TE_{22N} mode (72), the at least one cross coupling element having an angular position in relation to either the first or second characterizing vector (74, 76) equal to an integer multiple of 90 degrees.

13. The microwave resonator filter (100) of claim 12, wherein
the first and second cavities (60a, 60b) are collinear;
the at least one coupling element is formed in a common end wall (158) separating the first and second cavities (60a, 60b); and
the at least one cross coupling element comprises
a transverse angular iris (88), being transverse to the radius of the cavity (60) and having an angular position in relation to the first characterizing vector (74) equal to an integer multiple of 90 degrees, and/or
a radial iris (84) having an angular position in relation to the second characterizing vector (74) equal to an integer multiple of 90 degrees.

14. The microwave resonator filter (100) of claim 12, wherein
the first and second cavities (60a, 60b) are non-collinear;
the at least one coupling element is formed between adjacent sidewall portions (54) of the first and second cavities (60a, 60b); and
the at least one cross coupling element comprises
a longitudinal iris (83), being parallel to the longitudinal axis (64) of the cavity (60) and having an angular position in relation to the second characterizing vector (76) equal to an integer multiple of 90 degrees, and/or
a transverse angular iris (89) having an angular position in relation to the first characterizing vector (74) equal to an integer multiple of 90 degrees.

15. The microwave resonator filter (100) of claim 8, further comprising at least a first discontinuity formed within the first cavity (60a) for electromagnetically coupling the first TE_{22N} mode (70) with the second TE_{22N} mode (72), and at least a second discontinuity formed within the second cavity (60b) for electromagnetically coupling the third TE_{22N} mode with the fourth TE_{22N} mode (72).

16. The microwave resonator filter (100) of claim 15, wherein the first discontinuity is formed within the first cavity (60a) at a first location, and the second discontinuity is formed within the second cavity (60b) at a second location in relation to the first location to generate a transmission zero in the microwave resonator filter (100) by coupling the first and second TE_{22N} modes (70, 72) with a polarity opposite to the third and fourth TE_{22N} modes (70, 72).

Patentansprüche

1. Mikrowellenresonatorbaugruppe (50), die Folgendes umfasst:

eine Kammer (60), die von einem elektrisch leitenden zylindrischen Gehäuse (52) definiert wird, **dadurch gekennzeichnet, dass** in die Kammer (60) gestrahlte elektromagnetische Energie in mehreren Resonanzmoden reso-

niert, die eine doppelte TE_{22N}-Mode umfasst, wobei N gleich oder größer als eins ist;
einen Eingangsanschluss (66), der in dem zylindrischen Gehäuse vorgesehen ist, um eine erste TE_{22N}-Mode (70) mit einer ersten Polarisation in die Kammer (60) zu strahlen; und
eine in der Kammer (60) ausgebildete Diskontinuität zum elektromagnetischen Koppeln der ersten TE_{22N}-Mode (70) mit einer zweiten TE_{22N}-Mode (72) mit einer zweiten Polarisation orthogonal zur ersten Polarisation.

2. Mikrowellenresonatorbaugruppe (50) nach Anspruch 1, wobei
ein Feldmuster der ersten TE_{22N}-Mode (70) einen ersten charakterisierenden Vektor (74) definiert, der in Bezug auf eine Längsachse (64) der Kammer (60) radial projiziert, wobei der erste charakterisierende Vektor (74) dem entspricht, wo das Feldmuster der ersten TE_{22N}-Mode (70) eine maximale Radialkomponente und eine minimale Winkelkomponente hat;
ein Feldmuster der zweiten TE_{22N}-Mode (72) einen zweiten charakterisierenden Vektor (76) definiert, der in Bezug auf die Längsachse (64) radial projiziert und einen 45-Grad-Winkel mit dem ersten charakterisierenden Vektor (74) bildet, wobei der zweite charakterisierende Vektor (76) dem entspricht, wo das Feldmuster der zweiten TE_{22N}-Mode (72) eine maximale Radialkomponente oder eine minimale Winkelkomponente hat; und
die Diskontinuität an einer Stelle in der Kammer (60) mit einer Winkelposition zwischen dem ersten und dem zweiten charakterisierenden Vektor (74, 76) ausgebildet ist, wo die erste und die zweite TE_{22N}-Mode (70, 72) jeweils Nicht-Null-Feldkomponenten haben.

3. Mikrowellenresonatorbaugruppe (50) nach Anspruch 2, wobei die Winkelposition der Diskontinuität ein Winkelmittelpunkt zwischen dem ersten und dem zweiten charakterisierenden Vektor (74, 76) ist.

4. Mikrowellenresonatorbaugruppe (50) nach Anspruch 3, wobei der Eingangsanschluss (66) eine Winkelposition in Bezug auf den zweiten charakterisierenden Vektor (76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat.

5. Mikrowellenresonatorbaugruppe (50) nach Anspruch 2, 3 oder 4, die ferner mehrere Diskontinuitäten aufweist, die in der Kammer (60) ausgebildet sind, um die erste TE_{22N}-Mode (70) elektromagnetisch mit der zweiten TE_{22N}-Mode (72) zu koppeln, wobei jede an einer entsprechenden Stelle in der Kammer ausgebildete Diskontinuität eine Winkelposition in Bezug auf den ersten oder zweiten charakterisierenden Vektor (74, 76) von gleich 22,5 Grad plus einem ganzzahligen Vielfachen von 90 Grad hat, wobei die erste und zweite TE_{22N}-Mode (70, 72) jeweils Nicht-Null-Feldkomponenten haben.

6. Mikrowellenresonatorbaugruppe (50) nach Anspruch 2, die ferner mehrere Diskontinuitäten umfasst, die in der Kammer (60) ausgebildet sind, um eine Resonanzfrequenz der ersten TE_{22N}-Mode (70) oder der zweiten TE_{22N}-Mode (72) zu justieren, wobei jede Diskontinuität an einer entsprechenden Stelle in der Kammer (60) mit einer Winkelposition in Bezug auf den ersten oder den zweiten charakterisierenden Vektor (74, 76) von gleich einem ganzzahligen Vielfachen von 90 Grad ausgebildet ist, wobei die erste oder die zweite TE_{22N}-Mode (70, 72) Feldkomponenten im Wesentlichen größer als die andere aus erster und zweiter TE_{22N}-Mode (70, 72) hat.

7. Mikrowellenresonatorbaugruppe (50) nach einem der Ansprüche 2 bis 6, die ferner Folgendes umfasst:

wenigstens ein Direktkopplungselement, das in dem zylindrischen Gehäuse (52) vorgesehen ist, um die zweite TE_{22N}-Mode (72) aus der Kammer zu strahlen; und
wenigstens ein Kreuzkopplungselement, das in dem zylindrischen Gehäuse (52) vorgesehen ist, um die erste TE_{22N}-Mode (70) aus der Kammer zu strahlen.

8. Mikrowellenresonatorfilter (100), das mit mehreren Mikrowellenresonatorbaugruppen (50) realisiert ist, wobei das Resonatorfilter (100) Folgendes umfasst:

mehrere Kammern einschließlich wenigstens einer ersten Kammer (60a) und einer zweiten Kammer (60b), die sich neben der ersten Kammer (60a) befindet, wobei die erste Kammer (60a) und die zweite Kammer (60b) jeweils von einem entsprechenden elektrisch leitenden zylindrischen Gehäuse (52a, 52b) definiert werden, **dadurch gekennzeichnet, dass** in diese Kammer gestrahlte elektromagnetische Energie in mehreren Resonanzmoden resoniert, die eine doppelte TE_{22N}-Mode umfassen, wobei N gleich oder größer als eins ist; und
wenigstens ein Kopplungselement zum Strahlen von elektromagnetischer Energie zwischen der ersten Kammer (60a) und der zweiten Kammer (60b), wobei das wenigstens eine Kopplungselement so konfiguriert ist, dass es eine erste TE_{22N}-Mode (70), die in der ersten Kammer resoniert, elektromagnetisch mit einer vierten TE_{22N}-Mode (70) koppelt, die in der zweiten Kammer resoniert, und eine zweite TE_{22N}-Mode (72), die in der ersten Kammer (60a) resoniert, mit einer dritten TE_{22N}-Mode (72), die in der zweiten Kammer (60b) resoniert, wobei die ers-

te und die vierte TE_{22N}-Mode (70) eine erste Polarisation haben und die zweite und dritte TE_{22N}-Mode (72) eine zweite Polarisation orthogonal zur ersten Polarisation haben.

9. Mikrowellenresonatorfilter (100) nach Anspruch 8, wobei
die erste TE_{22N}-Mode (70) einen ersten charakterisierenden Vektor (74) definiert, der in Bezug auf eine Längsachse (64) der ersten Kammer radial projiziert, wobei der erste charakterisierende Vektor (74) dem entspricht, wo die erste TE_{22N}-Mode (70) eine maximale Radialkomponente und eine Winkelkomponente von null hat;
die zweite TE_{22N}-Mode (72) einen zweiten charakterisierenden Vektor (76) definiert, der in Bezug auf die Längsachse (64) radial projiziert und einen 45-Grad-Winkel mit dem ersten charakterisierenden Vektor (74) bildet, wobei der zweite charakterisierende Vektor (76) dem entspricht, wo die zweite TE_{22N}-Mode (72) ein maximales Radialkomponenten und eine Winkelkomponente von null hat; und
das wenigstens eine Kopplungselement wenigstens ein Direktkopplungselement zum elektromagnetischen Koppeln der zweiten TE_{22N}-Mode (72) mit der dritten TE_{22N}-Mode (72) umfasst, wobei das wenigstens eine Direktkopplungselement eine Winkelposition in Bezug auf entweder den ersten oder den zweiten charakterisierenden Vektor (74, 76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat.

10. Mikrowellenresonatorfilter (100) nach Anspruch 9, wobei
die erste und zweite Kammer (60a, 60b) kollinear sind;
das wenigstens eine Kopplungselement in einer gemeinsamen Endwand (158) ausgebildet ist, die die erste und die zweite Kammer (60a, 60b) voneinander trennt; und
das wenigstens eine Direktkopplungselement Folgendes umfasst:

eine transversale anguläre Iris (90), durch die der Radius der Kammer (60) verläuft und die eine Winkelposition in Bezug auf den zweiten charakterisierenden Vektor (76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat, und/oder
eine radiale Iris (86) mit einer Winkelposition in Bezug auf den ersten charakterisierenden Vektor (74) von gleich einem ganzzahligen Vielfachen von 90 Grad.

11. Mikrowellenresonatorfilter (100) nach Anspruch 9, wobei
die erste und zweite Kammer (60a, 60b) nicht kollinear sind;
das wenigstens eine Kopplungselement zwischen benachbarten Seitenwandabschnitten (54) der ersten und zweiten Kammer (60a, 60b) ausgebildet ist; und
das wenigstens eine Direktkopplungselement Folgendes umfasst:

eine transversale anguläre Iris (85), durch die der Radius der Kammer (60) verläuft und die eine Winkelposition in Bezug auf den zweiten charakterisierenden Vektor (76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat, und/oder
eine longitudinale Iris (83), die parallel zur Längsachse (64) der Kammer (60) verläuft und eine Winkelposition in Bezug auf den ersten charakterisierenden Vektor (74) von gleich einem ganzzahligen Vielfachen von 90 Grad hat.

12. Mikrowellenresonatorfilter (100) nach Anspruch 9, wobei das wenigstens eine Kopplungselement ferner wenigstens ein Kreuzkopplungselement zum elektromagnetischen Koppeln der ersten TE_{22N}-Mode (70) mit der vierten TE_{22N}-Mode (72) umfasst, wobei das wenigstens eine Kreuzkopplungselement eine Winkelposition in Bezug auf entweder den ersten oder den zweiten charakterisierenden Vektor (74, 76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat.

13. Mikrowellenresonatorfilter (100) nach Anspruch 12, wobei
die erste und die zweite Kammer (60a, 60b) kollinear sind;
das wenigstens eine Kopplungselement in einer gemeinsamen Endwand (158) ausgebildet ist, die die erste und die zweite Kammer (60a, 60b) voneinander trennt; und
das wenigstens eine Kreuzkopplungselement Folgendes umfasst:

eine transversale anguläre Iris (88), durch die der Radius der Kammer (60) verläuft und die eine Winkelposition in Bezug auf den ersten charakterisierenden Vektor (74) von gleich einem ganzzahligen Vielfachen von 90 Grad hat, und/oder
eine radiale Iris (84) mit einer Winkelposition in Bezug auf den zweiten charakterisierenden Vektor (74) von gleich einem ganzzahligen Vielfachen von 90 Grad.

14. Mikrowellenresonatorfilter (100) nach Anspruch 12, wobei
die erste und zweite Kammer (60a, 60b) nicht kollinear sind;
das wenigstens eine Kopplungselement zwischen benachbarten Seitenwandabschnitten (54) der ersten und zweiten Kammer (60a, 60b) ausgebildet ist;

und

das wenigstens eine Kreuzkopplungselement Folgendes umfasst:

eine longitudinale Iris (83), die parallel zur Längsachse (64) der Kammer (60) verläuft und eine Winkelposition in Bezug auf den zweiten charakterisierenden Vektor (76) von gleich einem ganzzahligen Vielfachen von 90 Grad hat, und/oder

eine transversale anguläre Iris (89) mit einer Winkelposition in Bezug auf den ersten charakterisierenden Vektor (74) von gleich einem ganzzahligen Vielfachen von 90 Grad.

15. Mikrowellenresonatorfilter (100) nach Anspruch 8, das ferner wenigstens eine Diskontinuität umfasst, die in der ersten Kammer (60a) zum elektromagnetischen Koppeln der ersten TE_{22N}-Mode (70) mit der zweiten TE_{22N}-Mode (72) ausgebildet ist, und wenigstens eine zweite Diskontinuität, die in der zweiten Kammer (60b) zum elektromagnetischen Koppeln der dritten TE_{22N}-Mode mit der vierten TE_{22N}-Mode (72) ausgebildet ist.

16. Mikrowellenresonatorfilter (100) nach Anspruch 15, wobei die erste Diskontinuität in der ersten Kammer (60a) an einer ersten Stelle ausgebildet ist und die zweite Diskontinuität in der zweiten Kammer (60b) an einer zweiten Stelle in Bezug auf die erste Stelle ausgebildet ist, um ein Übertragungsnull im Mikrowellenresonatorfilter (100) durch Koppeln der ersten und zweiten TE_{22N}-Mode (70, 72) mit einer Polarität entgegengesetzt zur dritten und vierten TE_{22N}-Mode (70, 72) zu erzeugen.

Claim 9, lines 9/10: "maximum radial component maximum" should probably read "maximum radial component". However, I have provided a literal translation.

Revendications

1. Ensemble de résonateur hyperfréquence (50) comprenant :

une cavité (60) définie par une enceinte cylindrique électriquement conductrice (52) **caractérisée en ce que** l'énergie électromagnétique rayonnée dans la cavité (60) résonne dans une pluralité de modes de résonance comprenant un mode TE_{22N} double, N étant supérieur ou égal à un ;

un port d'entrée (66) fourni dans l'enceinte cylindrique pour rayonner un premier mode TE_{22N} (70) ayant une première polarisation dans la cavité 60) ; et

une discontinuité formée dans la cavité (60) configurée pour coupler électromagnétiquement le premier mode TE_{22N} (70) à un deuxième mode TE_{22N} (72) ayant une seconde polarisation orthogonale à la première polarisation.

2. Ensemble de résonateur hyperfréquence (50) selon la revendication 1, dans lequel

un diagramme de champ du premier mode TE_{22N} (70) définit un premier vecteur de caractérisation (74) à projection radiale par rapport à un axe longitudinal (64) de la cavité (60), le premier vecteur de caractérisation (74) correspondant à l'emplacement où le diagramme de champ du premier mode TE_{22N} (70) a une composante radiale maximum et une composante angulaire minimum ;

un diagramme de champ du deuxième mode TE_{22N} (72) définit un second vecteur de caractérisation (76) à projection radiale par rapport à l'axe longitudinal (64) et formant un angle de 45 degrés avec le premier vecteur de caractérisation (74), le second vecteur de caractérisation (76) correspondant à l'emplacement où le diagramme de champ du deuxième mode TE_{22N} (72) a une composante radiale maximum et une composante angulaire minimum ; et

la discontinuité est formée à un emplacement dans la cavité (60) ayant une position angulaire intermédiaire entre les premier et second vecteurs de caractérisation (74, 76), où les premier et deuxième modes TE_{22N} (70, 72) ont chacun des composantes de champ non nulles.

3. Ensemble de résonateur hyperfréquence (50) selon la revendication 2, dans lequel la position angulaire de la discontinuité est un point milieu angulaire entre les premier et second vecteurs de caractérisation (74, 76).

4. Ensemble de résonateur hyperfréquence (50) selon la revendication 3, dans lequel le port d'entrée (66) a une position angulaire par rapport au second vecteur de caractérisation (76) égal à un multiple entier de 90 degrés.

5. Ensemble de résonateur hyperfréquence (50) selon l'une quelconque des revendications 2 , 3 ou 4, comprenant en outre une pluralité de discontinuités formées dans la cavité (60) pour coupler électromagnétiquement le premier mode TE_{22N} (70) au deuxième mode TE_{22N} (72), chaque discontinuité formée à un emplacement correspondant dans la cavité ayant une position angulaire par rapport au premier ou second vecteur de caractérisation (74, 76) égale à 22,5 degrés plus un multiple entier de 90degrés, les premier et deuxième modes TE_{22N} (70, 72) ayant chacun des composantes de champ non nulles.

6. Ensemble de résonateur hyperfréquence (50) selon la revendication 2, comprenant en outre une pluralité de discontinuités formées dans la cavité (60) pour régler une fréquence de résonance du premier mode TE_{22N} (70) ou du deuxième mode TE_{22N} (72), chaque discontinuité formée à un emplacement correspondant dans la cavité (60) ayant une position angulaire par rapport au premier ou second vecteur de caractérisation (74, 76) égale à un multiple entier de 90 degrés, l'un des premier et deuxième modes TE_{22N} (70, 72) ayant des composantes de champ sensiblement supérieures à l'autre des premier et deuxième modes TE_{22} (70, 72).

7. Ensemble de résonateur hyperfréquence (50) selon l'une quelconque des revendications 2 à 6, comprenant en outre
au moins un élément de couplage direct fourni dans l'enceinte cylindrique (52) pour rayonner le deuxième mode TE_{22N} (72) hors de la cavité ; et
au moins un élément de couplage croisé fourni dans l'enceinte cylindrique (52) pour rayonner le premier mode TE_{22N} (70) hors de la cavité.

8. Filtre de résonateur hyperfréquence (100) réalisé au moyen d'une pluralité d'ensembles de résonateur hyperfréquence (50), le filtre de résonateur (100) comprenant :

une pluralité de cavités comportant au moins une première cavité (60a) et une seconde cavité (60b) située à proximité de la première cavité (60a), chacune de la première cavité (60a) et de la seconde cavité (60b) définie par une enceinte cylindrique électriquement conductrice correspondante (52a, 52b) étant **caractérisée en ce que** l'énergie électromagnétique rayonnée dans cette cavité résonne dans une pluralité de modes de résonance comprenant un mode TE_{22N} double, N étant supérieur ou égal à un ; et
au moins un élément de couplage pour rayonner une énergie électromagnétique entre la première cavité (60a) et la seconde cavité (60b), l'au moins un élément de couplage étant configuré pour coupler électromagnétiquement un premier mode TE_{22N} (70) résonnant dans la première cavité à un quatrième mode TE_{22N} (70) résonnant dans la seconde cavité, et un deuxième mode TE_{22N} (72) résonnant dans la première cavité (60a) à un troisième mode TE_{22N} (72) résonnant dans la seconde cavité (60b), les premier et quatrième modes TE_{22N} (70) ayant une première polarisation et les deuxième et troisième modes TE_{22N} (72) ayant une seconde polarisation orthogonale à la première polarisation.

9. Filtre de résonateur hyperfréquence (100) selon la revendication 8, dans lequel
le premier mode TE_{22N} (70) définit un premier vecteur de caractérisation (74) à projection radiale par rapport à un axe longitudinal (64) de la première cavité, le premier vecteur de caractérisation (74) correspondant à l'emplacement où le premier mode TE_{22N} (70) a une composante radiale maximum et une composante angulaire nulle ;
le deuxième mode TE_{22N} (72) définit un second vecteur de caractérisation (76) à projection radiale par rapport à l'axe longitudinal (64) et formant un angle de 45 degrés avec le premier vecteur de caractérisation (74), le second vecteur de caractérisation (76) correspondant à l'emplacement où le second mode TE_{22N} (72) a une composante radiale maximum et une composante angulaire nulle ; et
l'au moins un élément de couplage comprend au moins un élément de couplage direct pour coupler électromagnétiquement le deuxième mode TE_{22N} (72) au troisième mode TE_{22N} (72), l'au moins un élément de couplage direct ayant une position angulaire par rapport au premier ou deuxième vecteur de caractérisation (74, 76) égale à un multiple entier de 90 degrés.

10. Filtre de résonateur hyperfréquence (100) selon la revendication 9, dans lequel les première et seconde cavités (60a, 60b) sont colinéaires ;
l'au moins un élément de couplage est formé dans une paroi d'extrémité commune (158) séparant les première et seconde cavités (60a, 60b) ; et
l'au moins un élément de couplage direct comprend un iris angulaire transversal (90), transversal au rayon de la cavité (60) et ayant une position angulaire par rapport au second vecteur de caractérisation (76) égale à un multiple entier de 90 degrés, et/ou un iris radial (86) ayant une position angulaire par rapport au premier vecteur de caractérisation (74) égale à un multiple entier de 90 degrés.

11. Filtre de résonateur hyperfréquence (100) selon la revendication 9, dans lequel
les première et seconde cavités (60a, 60b) sont non colinéaires ;
l'au moins un élément de couplage est formé entre des parties de paroi latérale adjacentes (54) des première et seconde cavités (60a, 60b) ; et
l'au moins un élément de couplage direct comprend un iris angulaire transversal (85), transversal au rayon de la cavité (60) et ayant une position angulaire par rapport au second vecteur de caractérisation (76) égale à un multiple entier de 90 degrés, et/ou un iris longitudinal (83), parallèle à l'axe longitudinal (64) de la cavité (60) et ayant une position angulaire par rapport au premier vecteur de caractérisation (74) égale à un multiple entier de 90 degrés.

12. Filtre de résonateur hyperfréquence (100) selon la revendication 9, dans lequel l'au moins un élément de couplage comprend en outre au moins un élément de couplage croisé pour coupler électromagnétiquement le premier mode TE_{22N} (70) au quatrième mode TE_{22N} (72), l'au moins un élément de couplage croisé ayant une position angulaire par rapport au premier ou deuxième vecteur de caractérisation (74, 76) égale à un multiple entier de 90 degrés.

13. Filtre de résonateur hyperfréquence (100) selon la revendication 12, dans lequel les première et seconde cavités (60a, 60b) sont colinéaires ;
l'au moins un élément de couplage est formé dans une paroi d'extrémité commune (158) séparant les première et seconde cavités (60a, 60b) ; et
l'au moins un élément de couplage croisé comprend un iris angulaire transversal (88), transversal au rayon de la cavité (60) et ayant une position angulaire par rapport au premier vecteur de caractérisation (74) égale à un multiple entier de 90 degrés, et/ou un iris radial (86) ayant une position angulaire par rapport au second vecteur de caractérisation (74) égale à un multiple entier de 90 degrés.

14. Filtre de résonateur hyperfréquence (100) selon la revendication 12, dans lequel les première et seconde cavités (60a, 60b) sont non colinéaires ;
l'au moins un élément de couplage est formé entre des parties de paroi latérale adjacentes (54) des première et seconde cavités (60a, 60b) ; et
l'au moins un élément de couplage croisé comprend un iris longitudinal (83), parallèle à l'axe longitudinal (64) de la cavité (60), et ayant une position angulaire par rapport au second vecteur de caractérisation (76) égale à un multiple entier de 90 degrés, et/ou un iris angulaire transversal (89) ayant une position angulaire par rapport au premier vecteur de caractérisation (74) égale à un multiple entier de 90 degrés.

15. Filtre de résonateur hyperfréquence (100) selon la revendication 8, comprenant en outre au moins une première discontinuité formée dans la première cavité (60a) pour coupler électromagnétiquement le premier mode TE_{22N} (70) au deuxième mode TE_{22N} (72), et au moins une seconde discontinuité formée dans la seconde cavité (60b) pour coupler électromagnétiquement le troisième mode TE_{22N} au quatrième mode TE_{22N}.

16. Filtre de résonateur hyperfréquence (100) selon la revendication 15, dans lequel la première discontinuité est formée dans la première cavité (60a) à un premier emplacement, et la seconde discontinuité est formée dans la seconde cavité (60b) à un second emplacement par rapport au premier emplacement pour générer un zéro de transmission dans le filtre de résonateur hyperfréquence (100) en couplant les premier et deuxième modes TE_{22N} (70, 72) d'une pluralité opposée aux troisième et quatrième modes TE_{22N} (70,72).

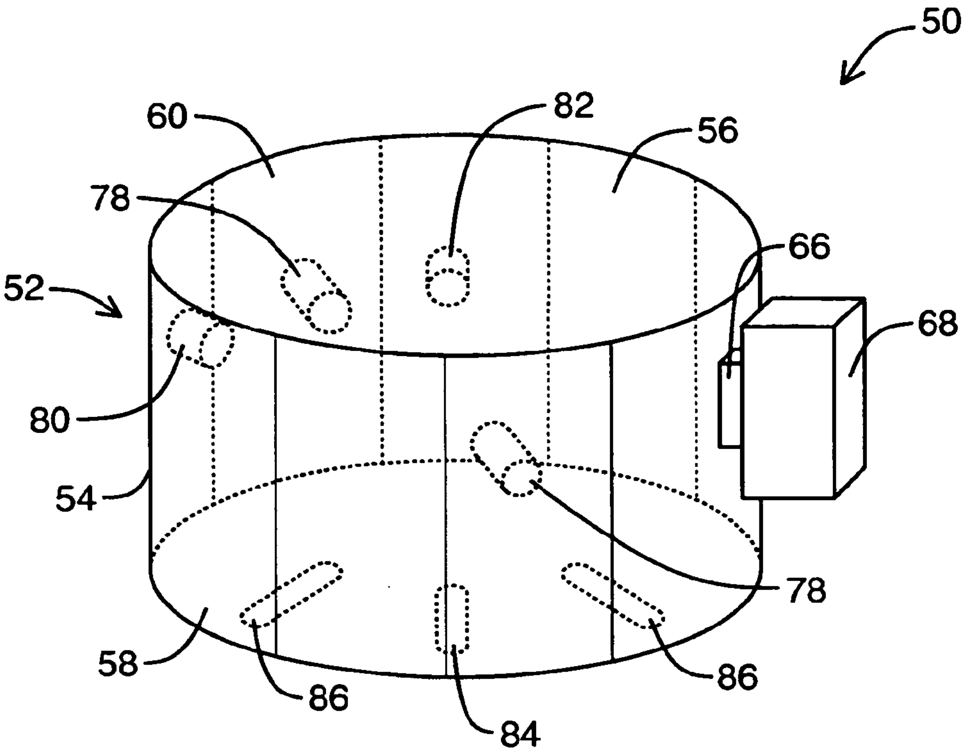
50
60
82
56
78
66
52
68
80
54
78
58
86
86
84

FIG. 1A

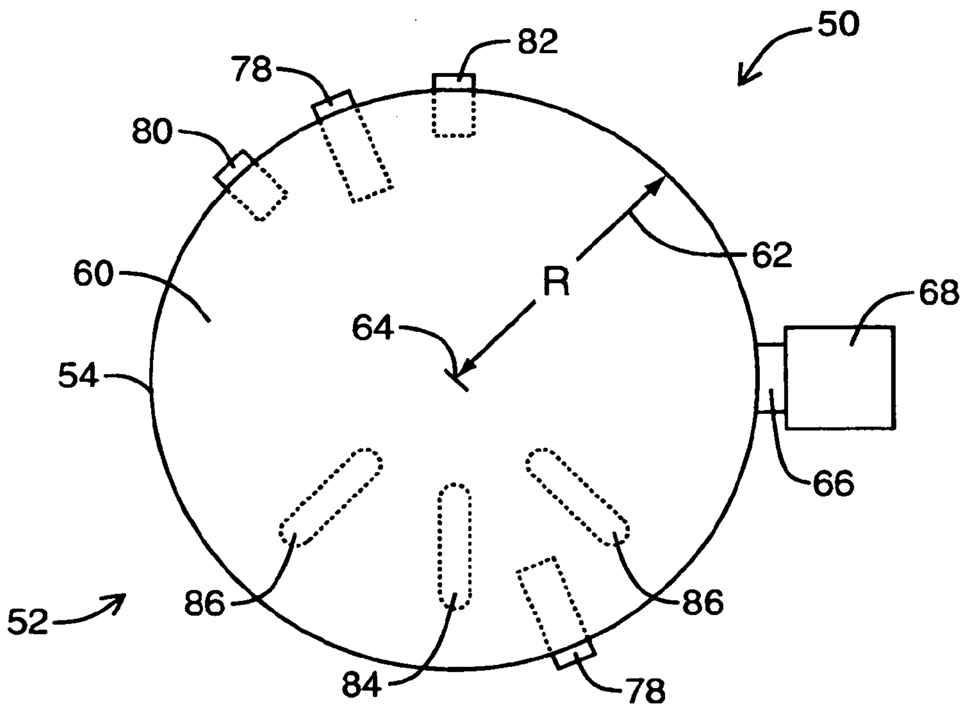
50
82
78
80
62
60
R
68
64
54
66
86
86
52
84
78

FIG. 1B

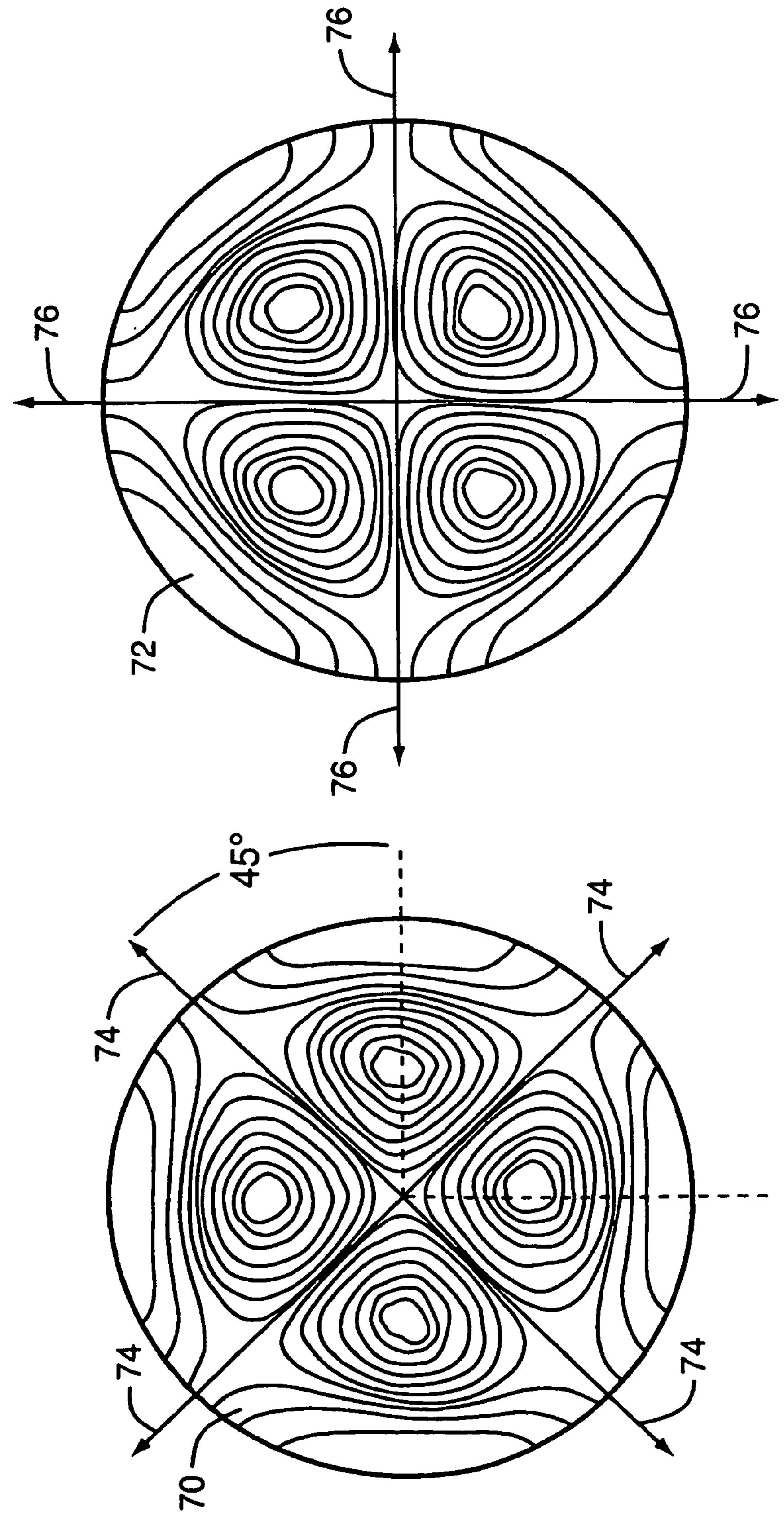

FIG. 2

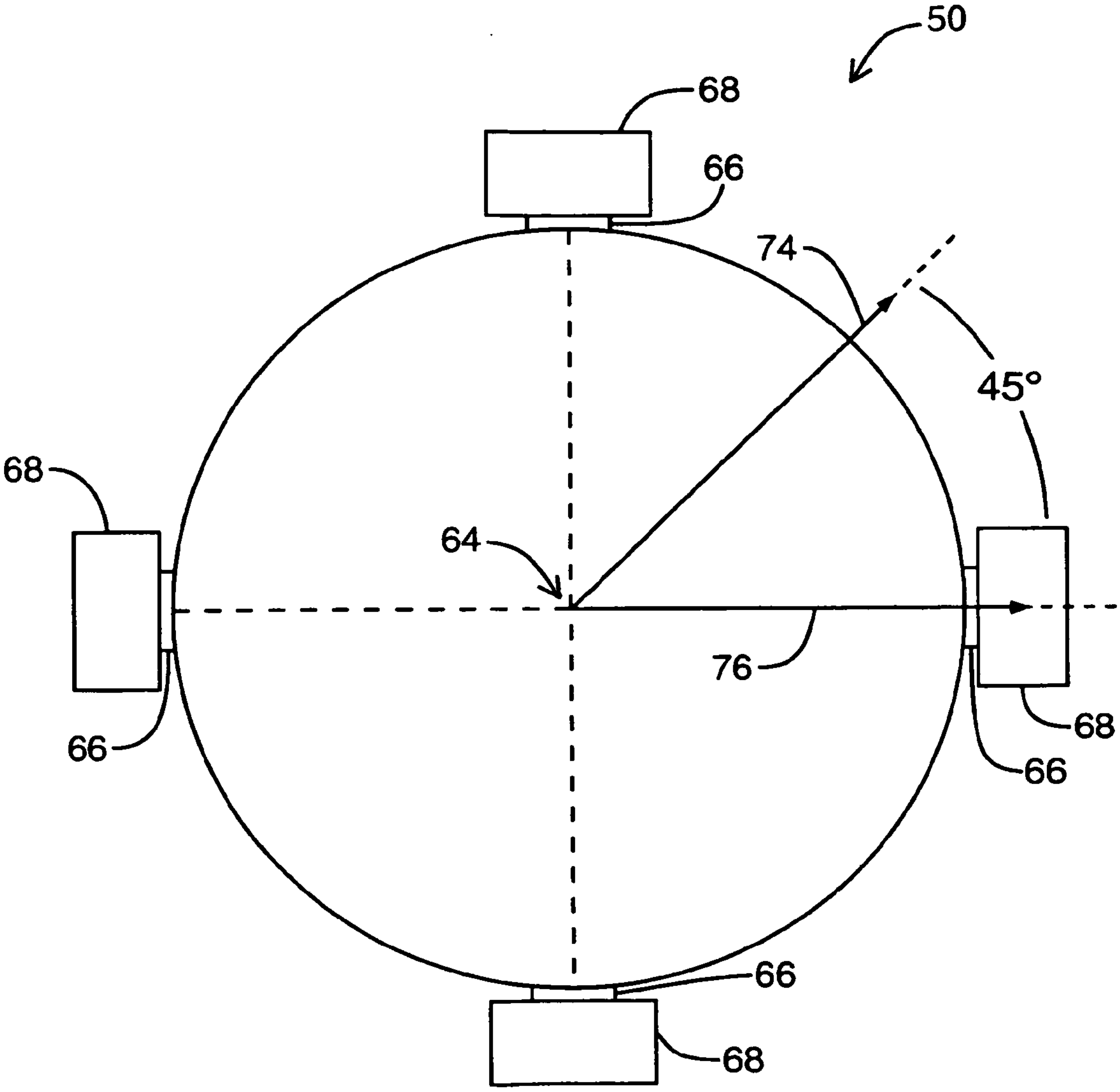

FIG. 3

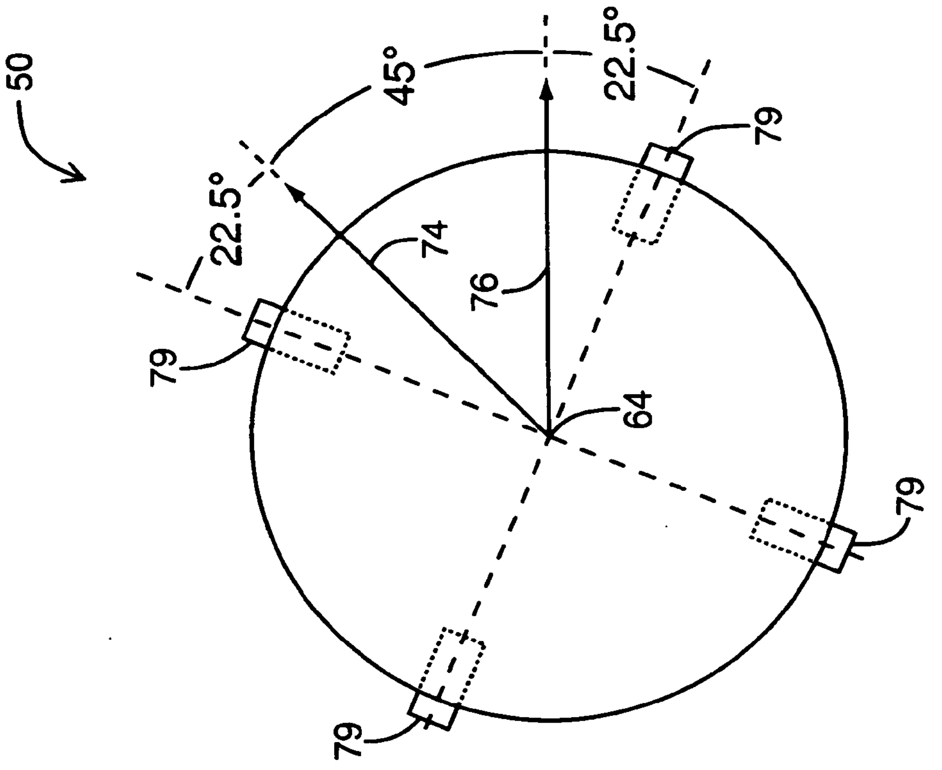

FIG. 4B

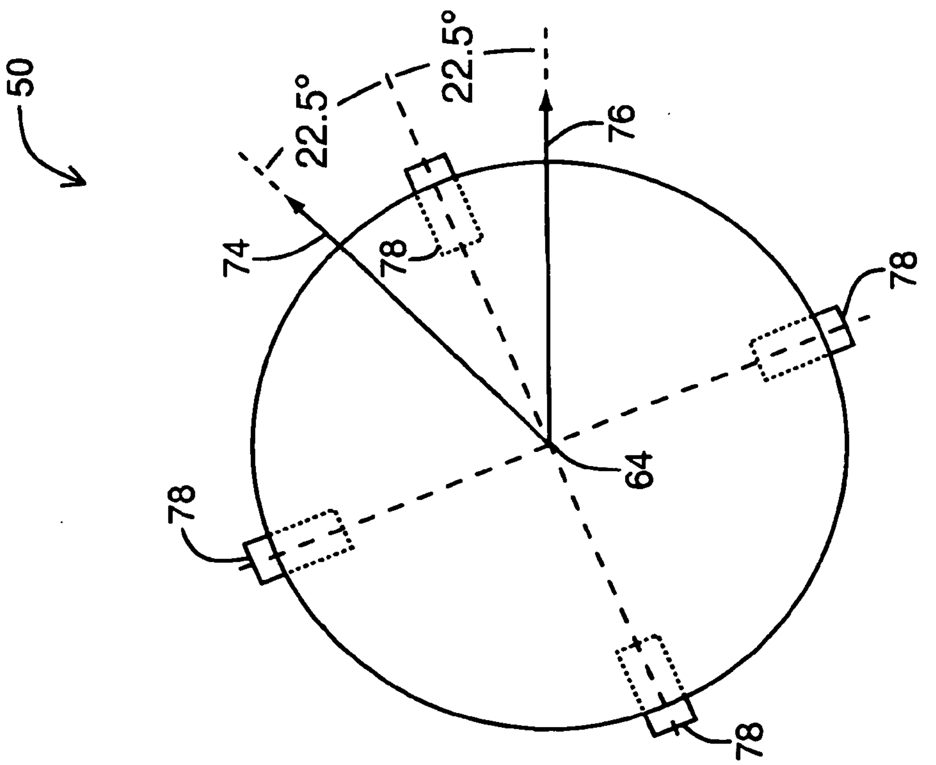

FIG. 4A

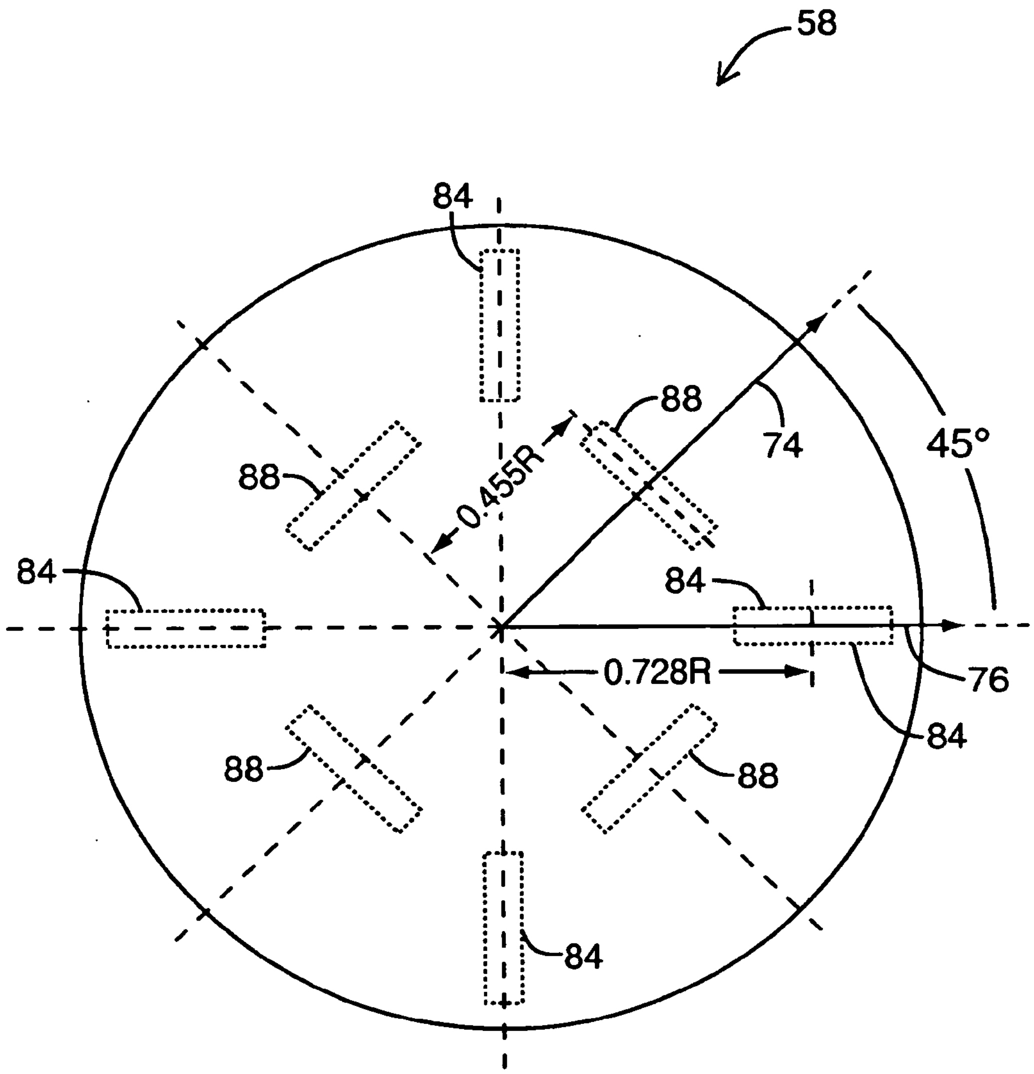

FIG. 5A

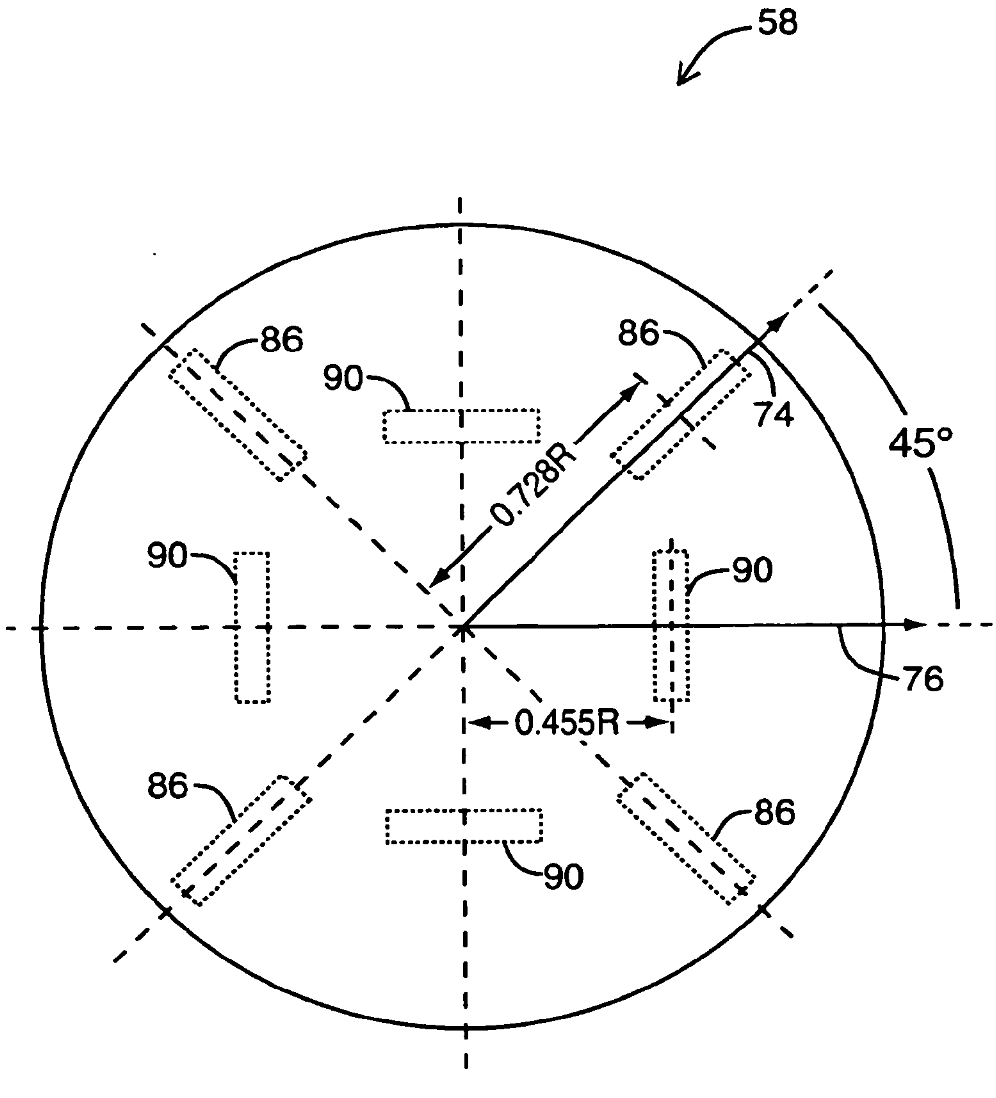

FIG. 5B

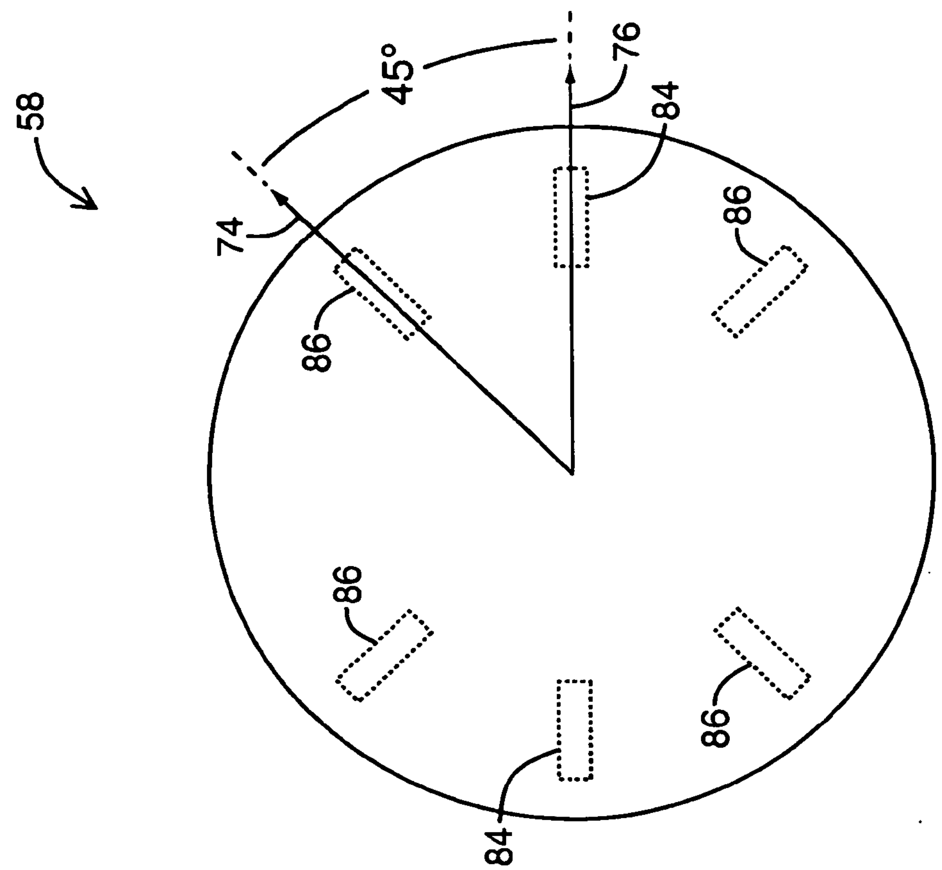

FIG. 6B

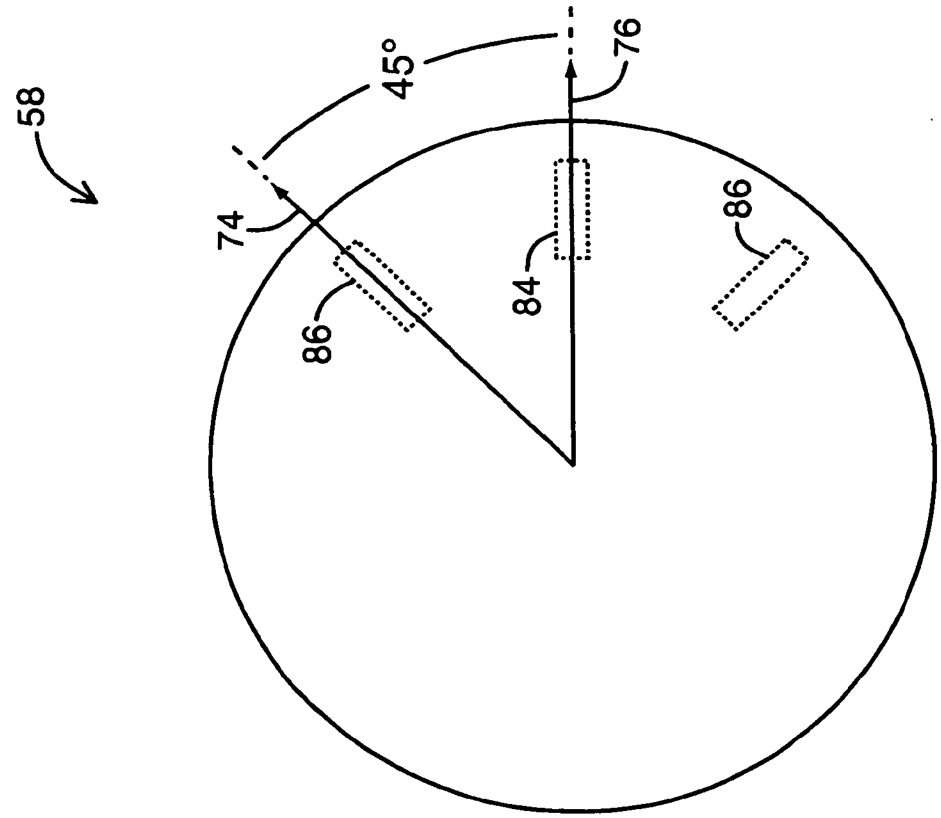

FIG. 6A

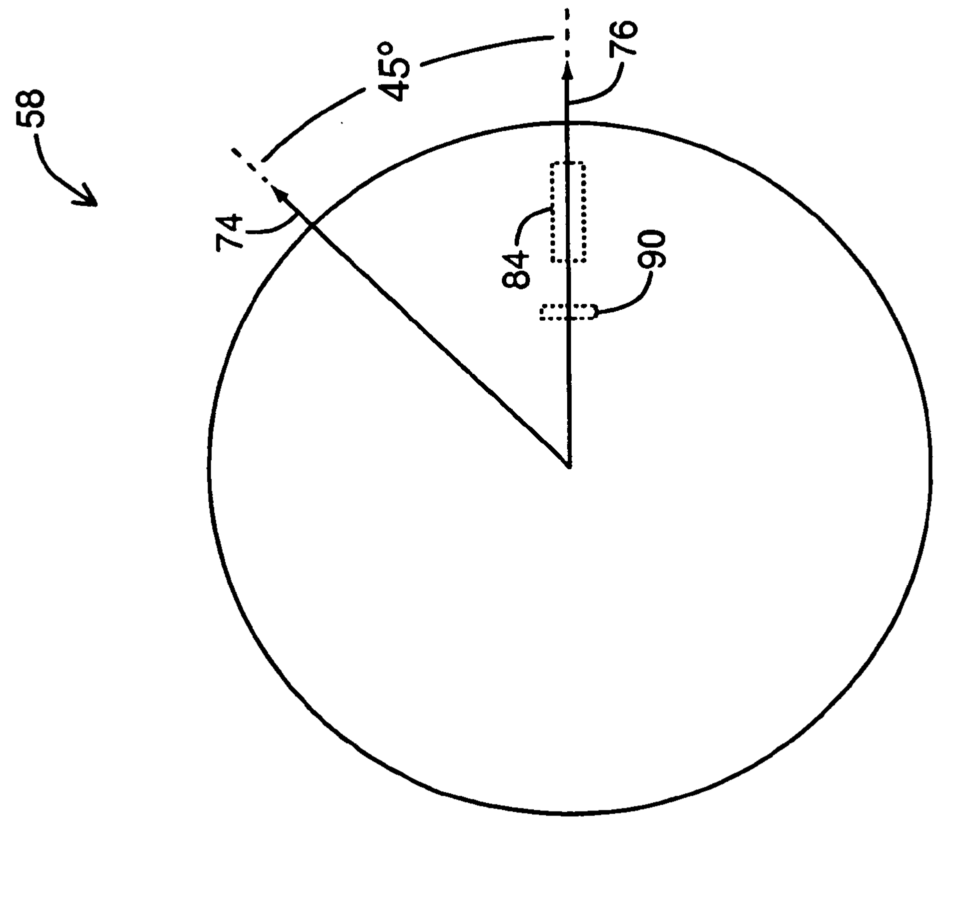

FIG. 6C

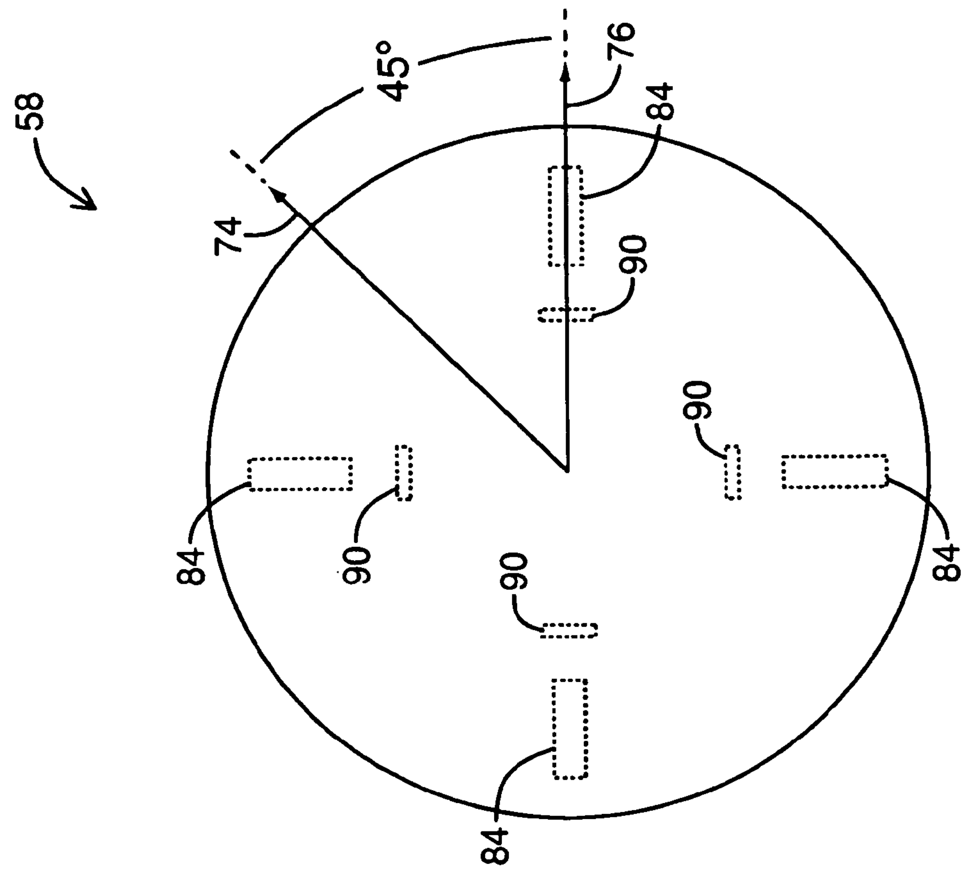

FIG. 6D

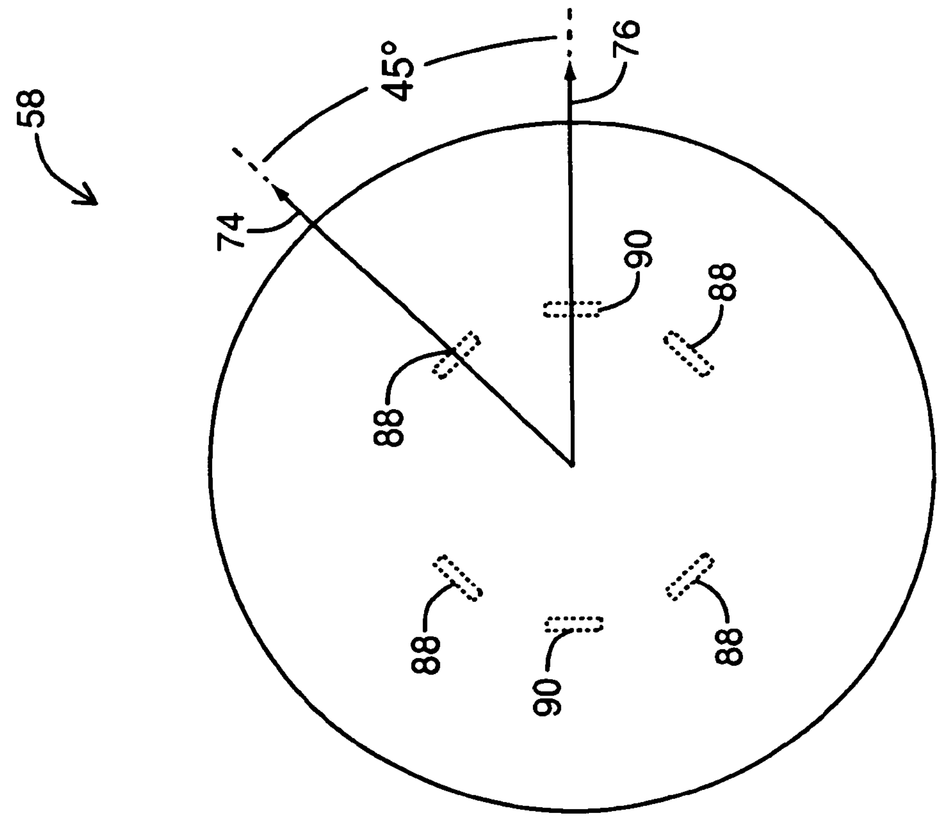

FIG. 6E

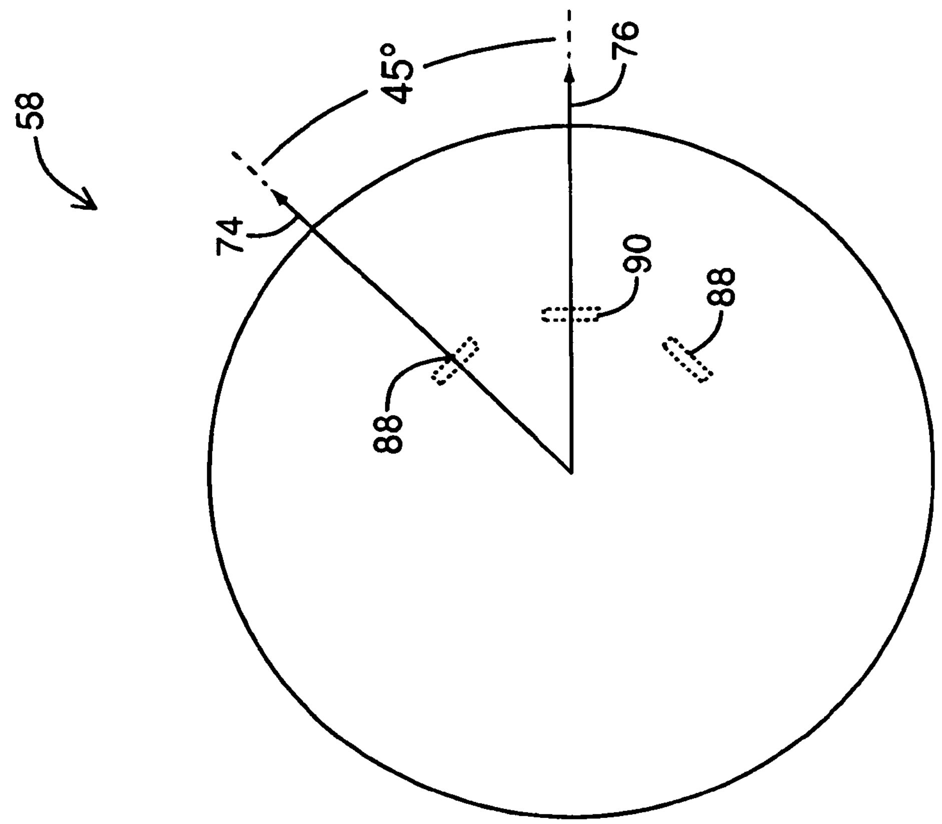

FIG. 6F

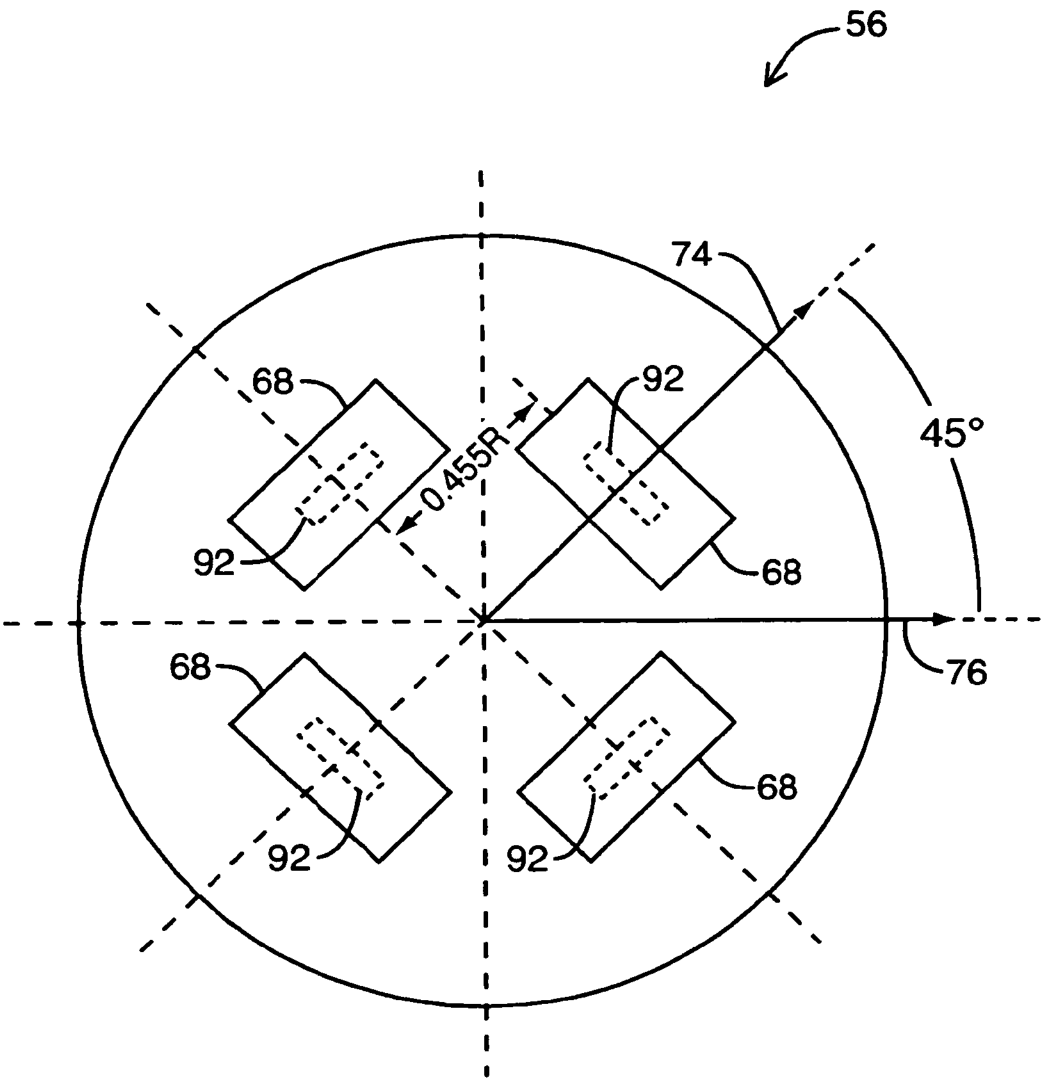

FIG. 7A

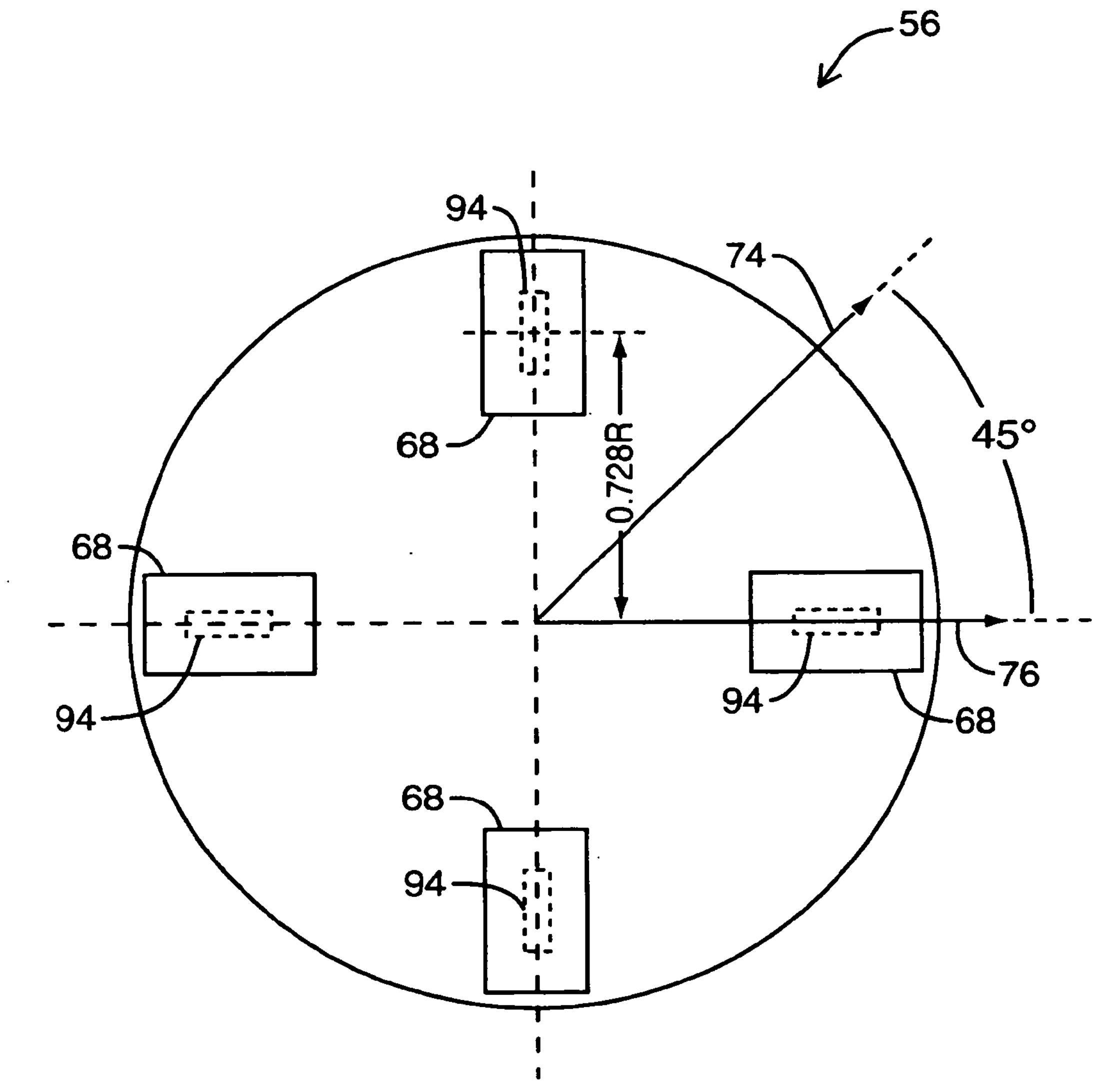

FIG. 7B

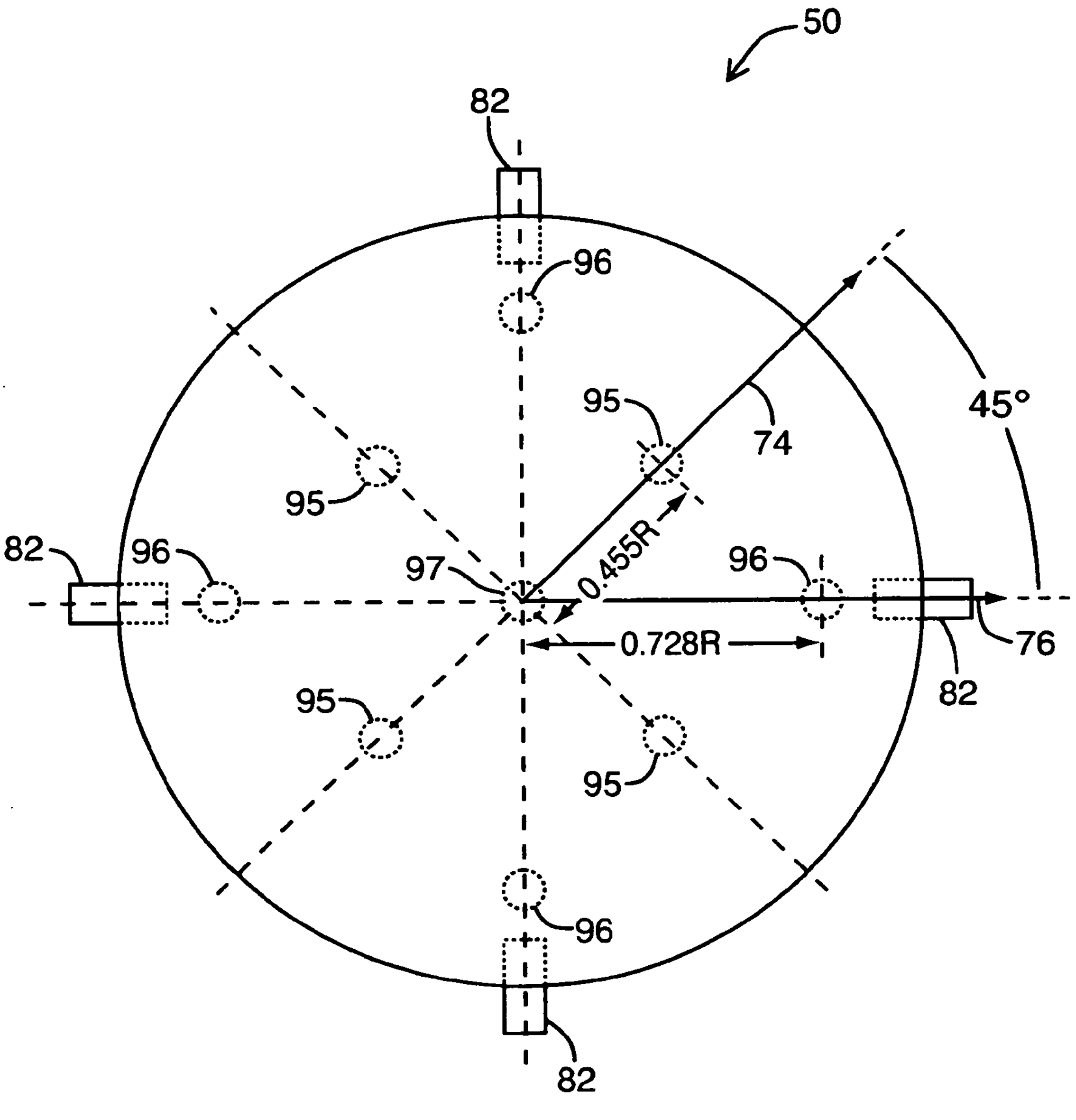

FIG. 8A

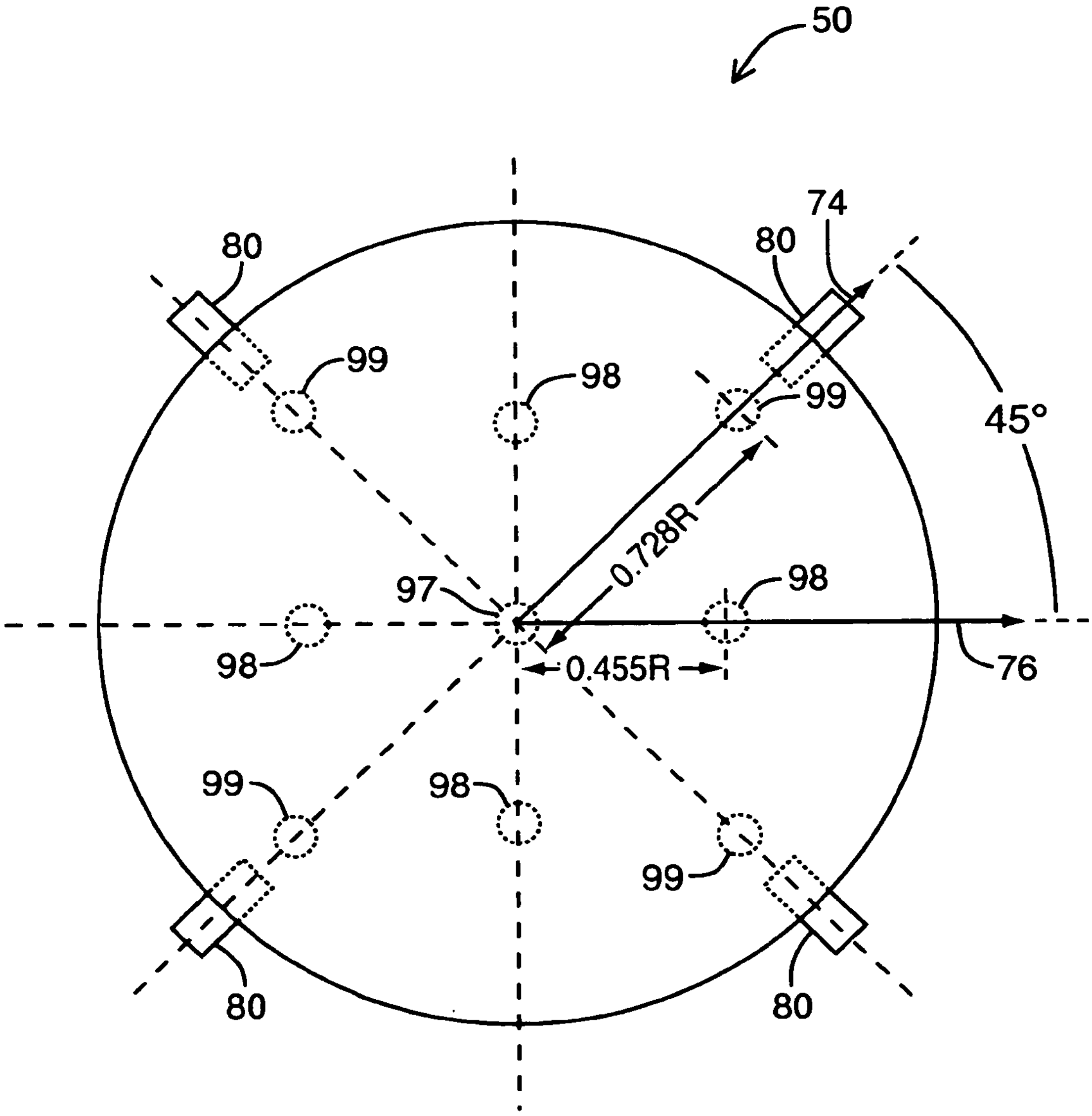

FIG. 8B

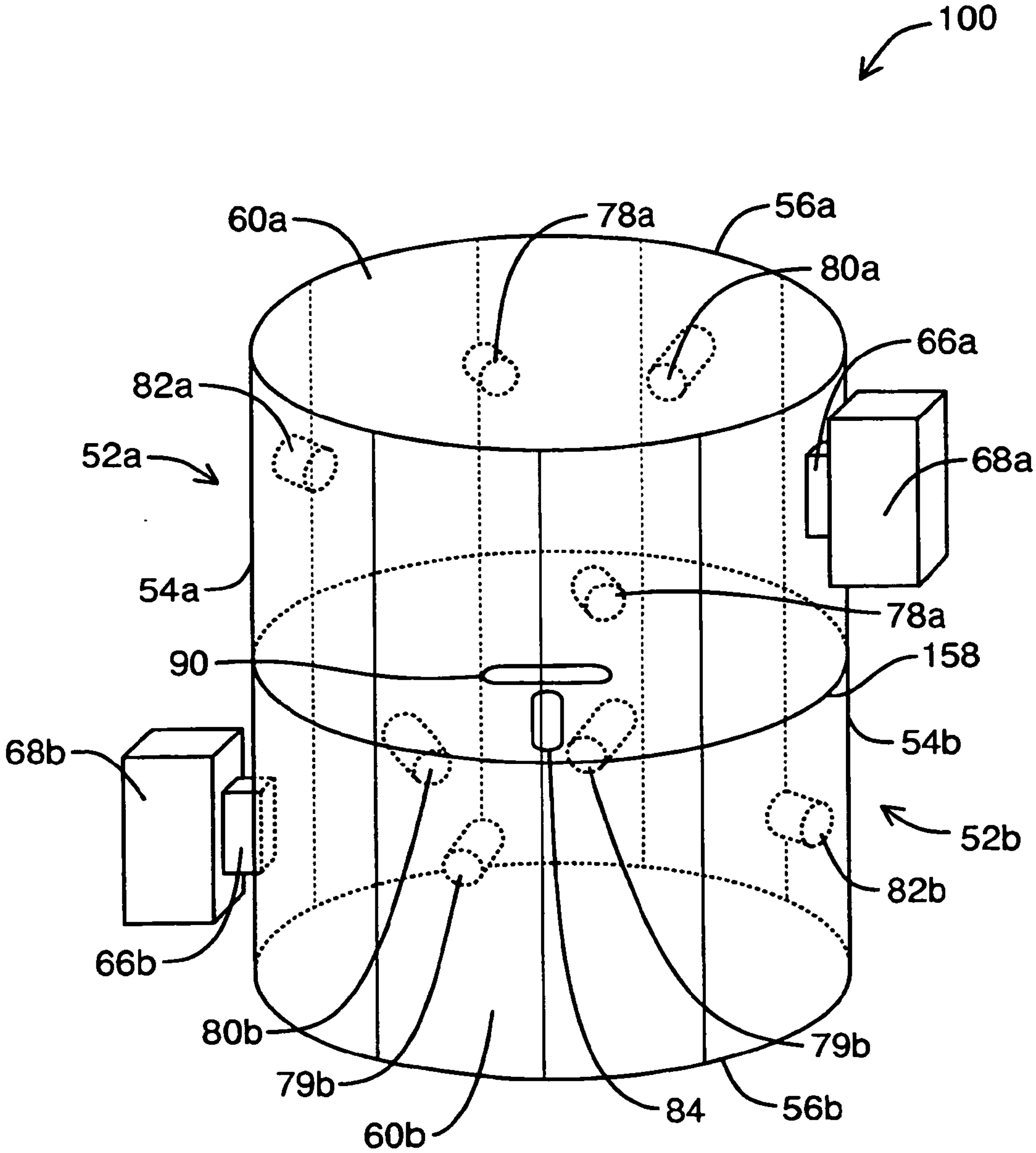
100
60a
78a
56a
80a
66a
82a
52a
68a
54a
78a
90
158
54b
68b
52b
82b
66b
80b
79b
79b
60b
84
56b

FIG. 9A

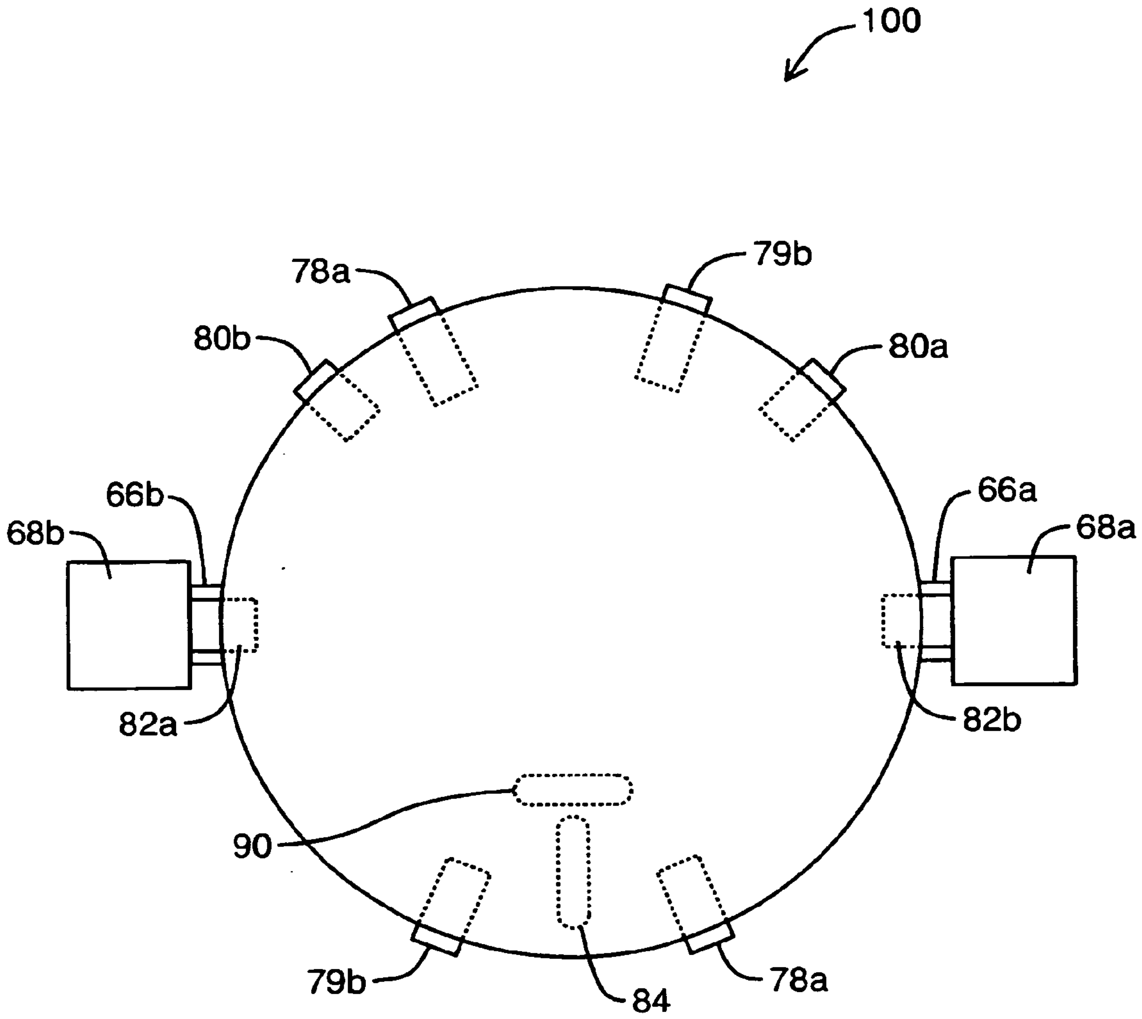

FIG. 9B

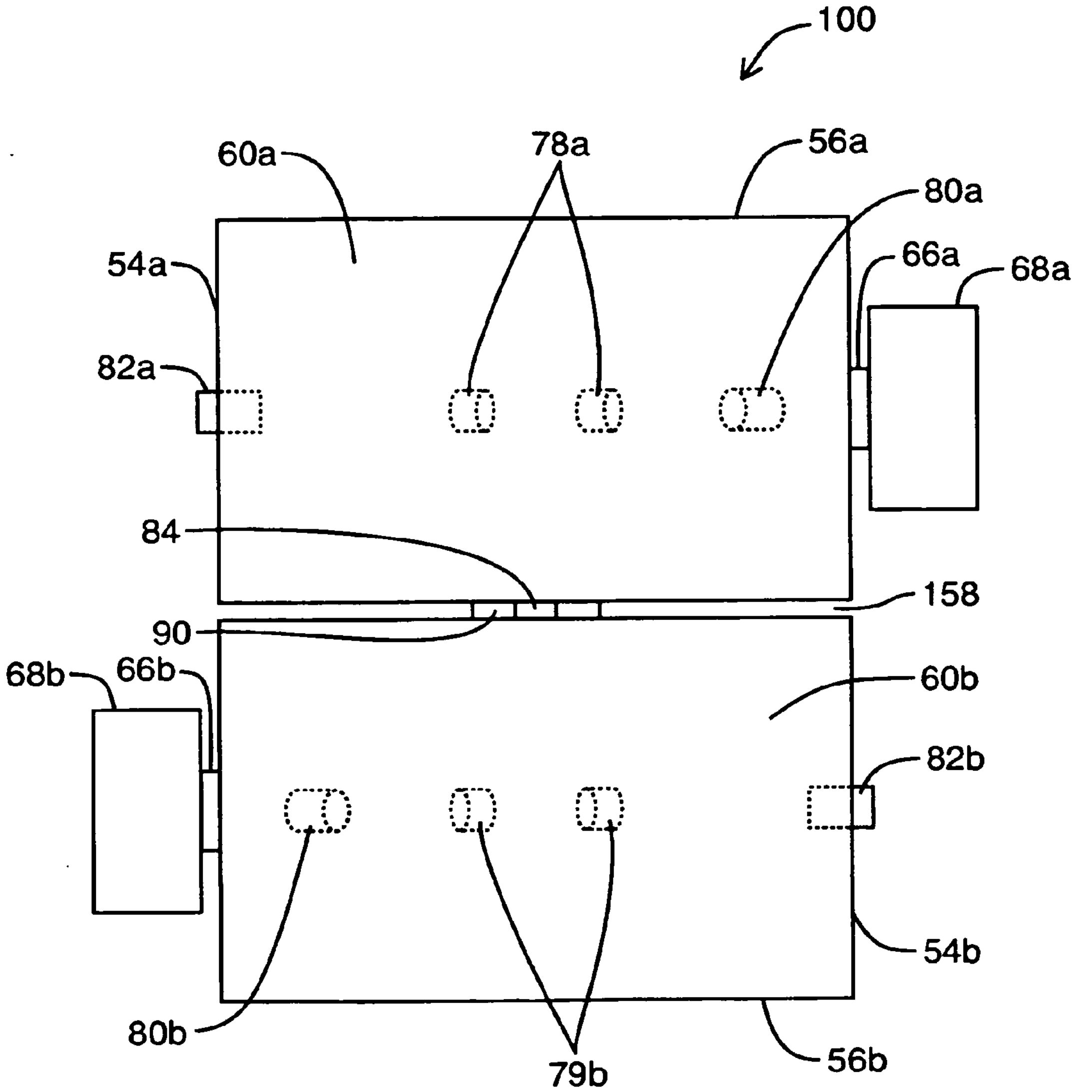
100
60a
78a
56a
80a
54a
66a
68a
82a
84
158
90
68b
66b
60b
82b
54b
80b
79b
56b

FIG. 9C

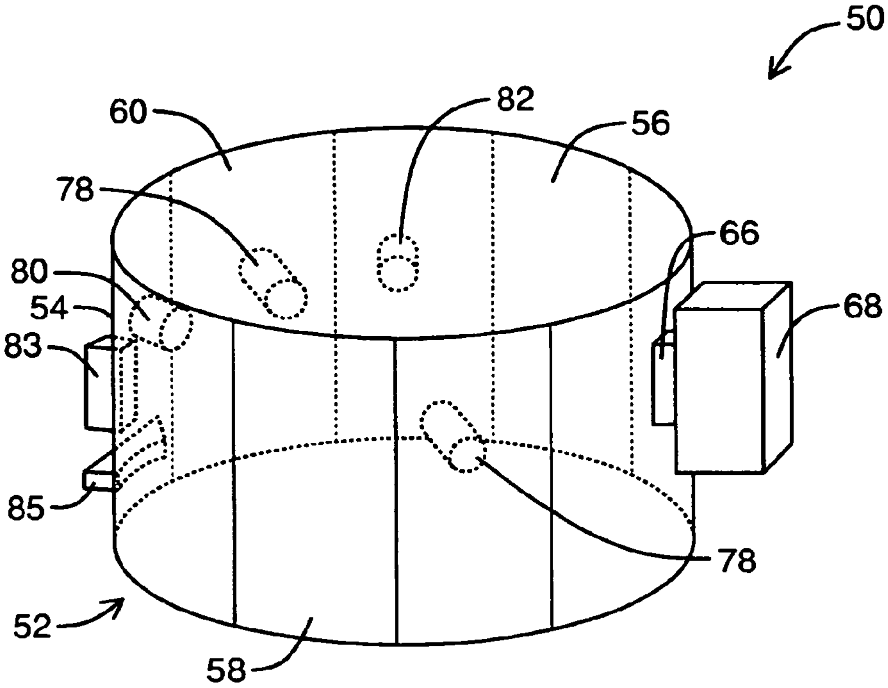

FIG. 10A

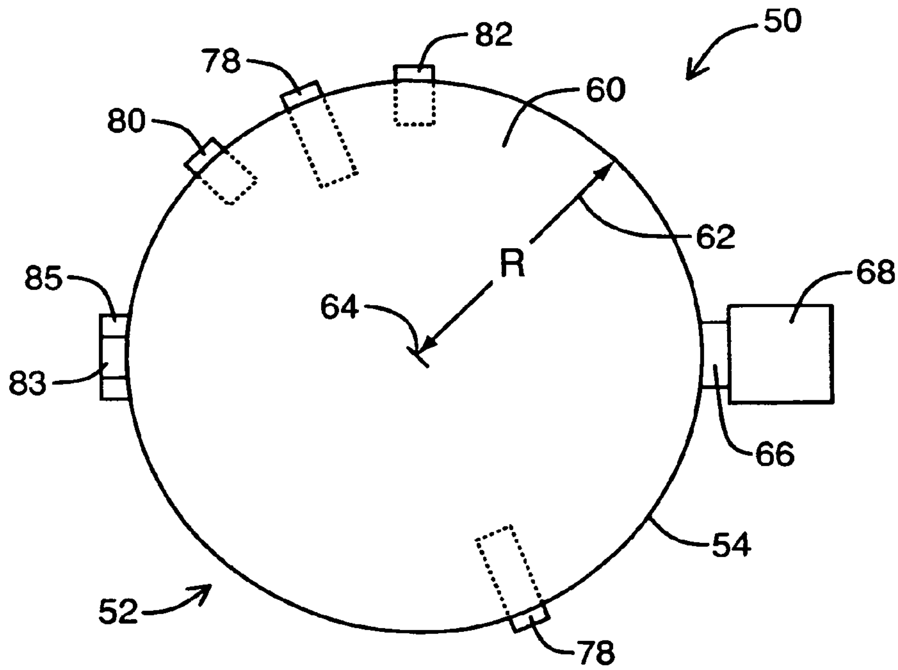

FIG. 10B

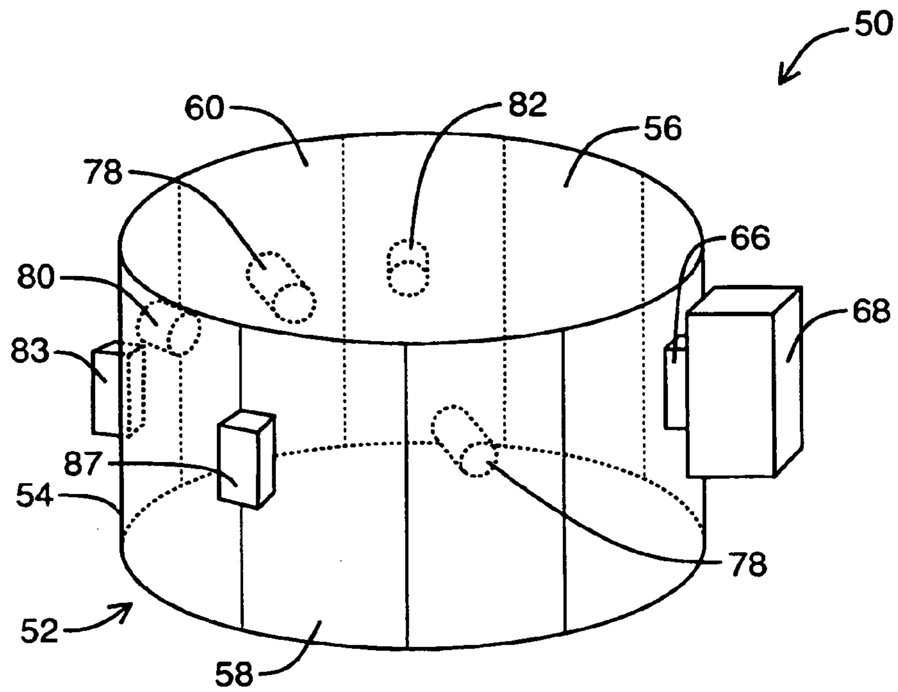

FIG. 11A

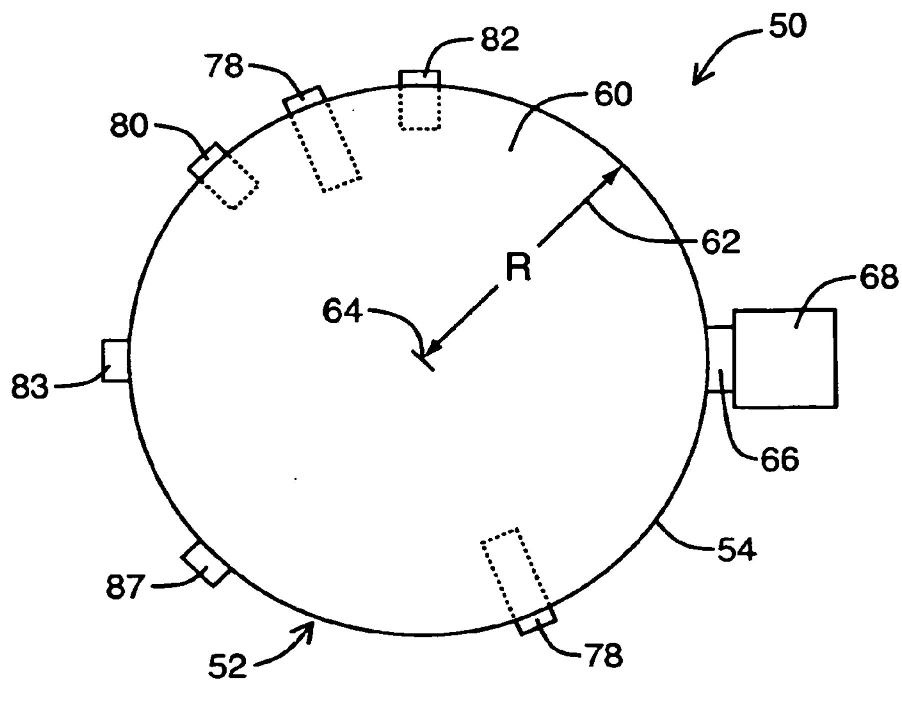

FIG. 11B

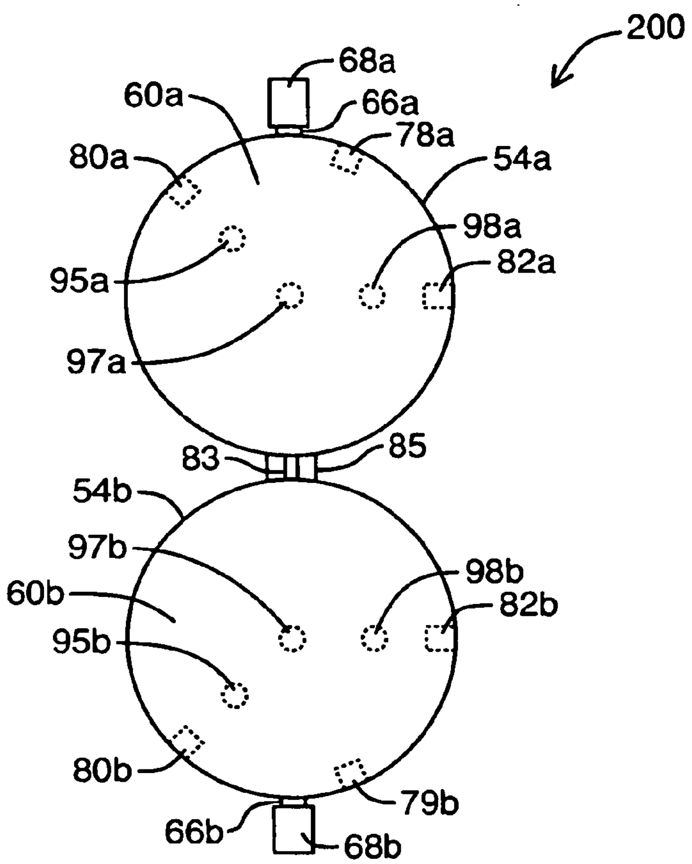

FIG. 12A

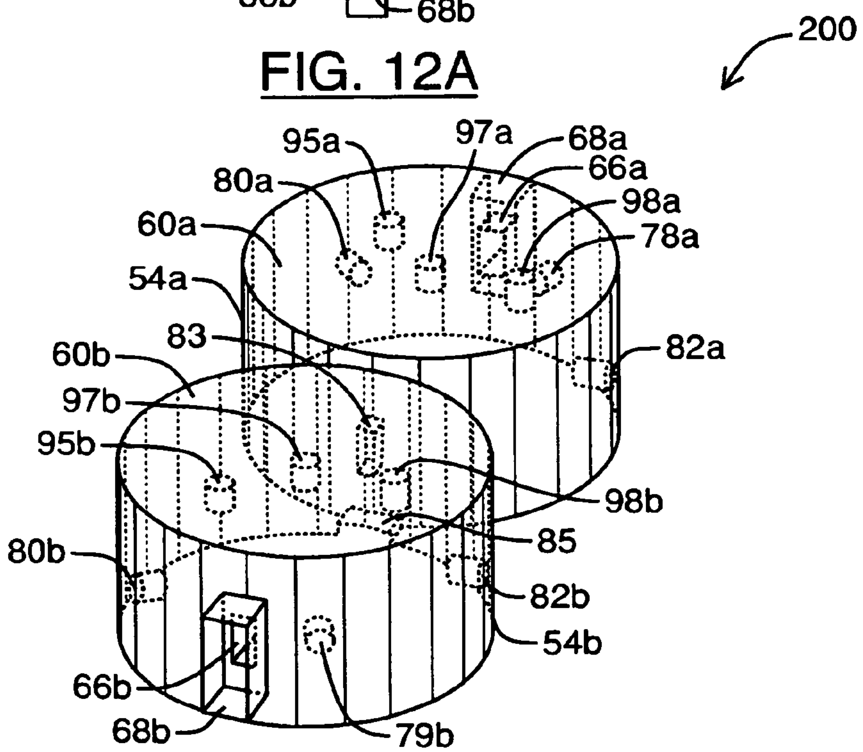

FIG. 12B

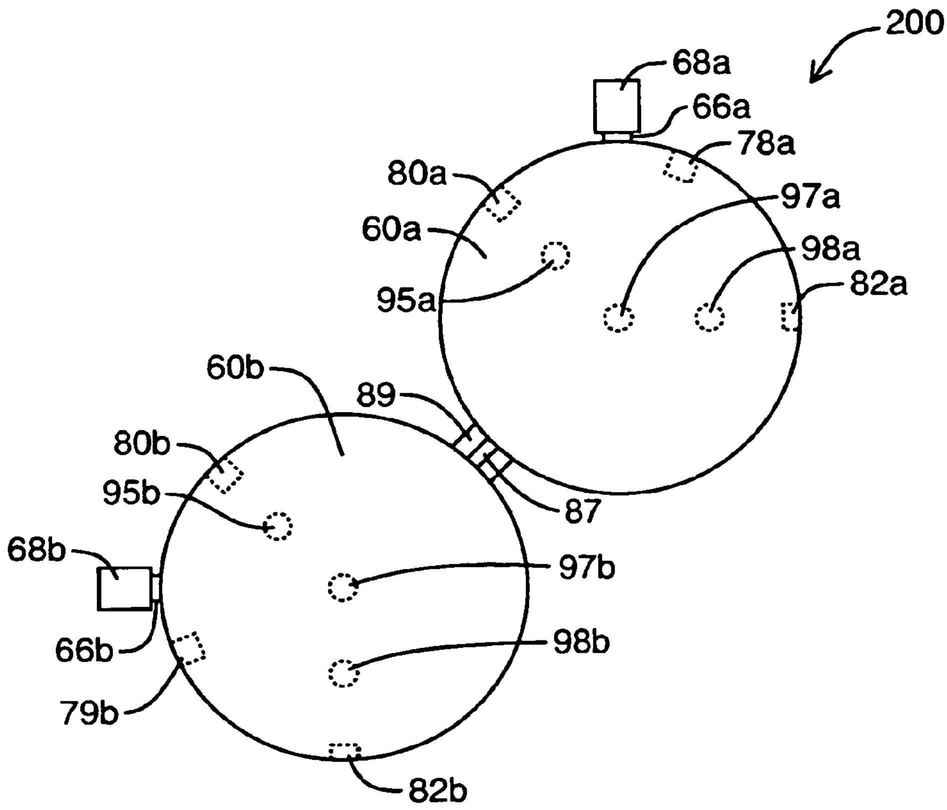

FIG. 13A

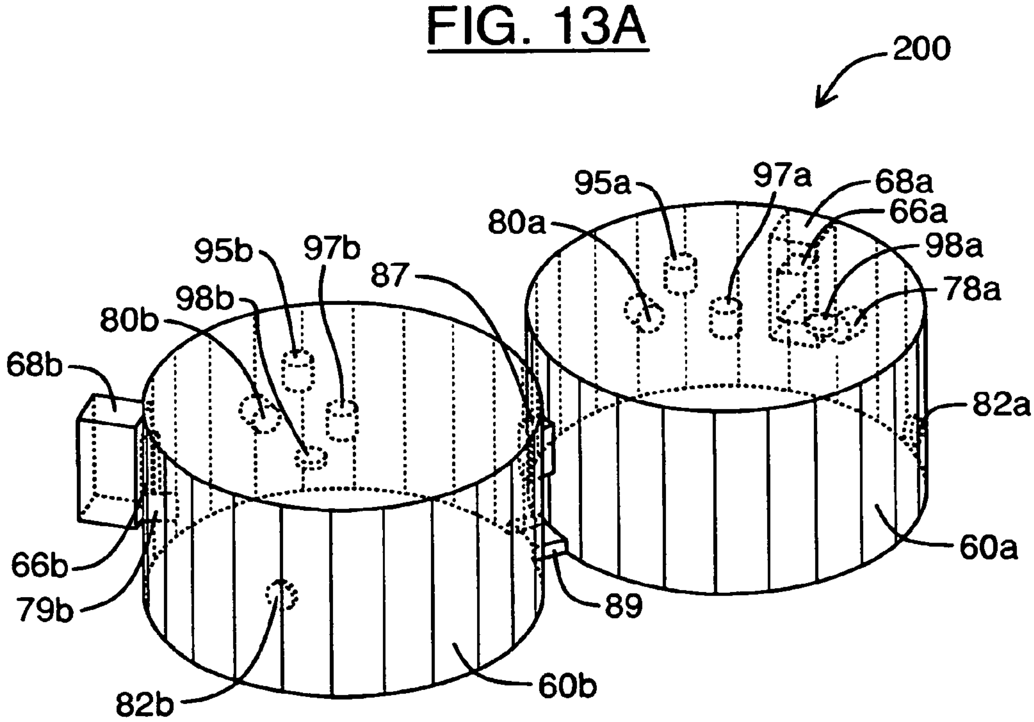

FIG. 13B

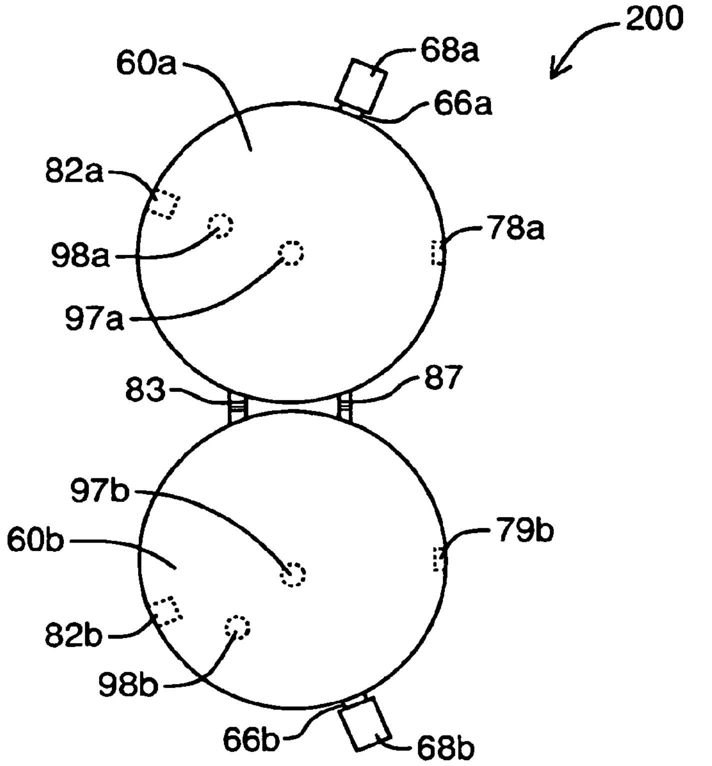

FIG. 14A

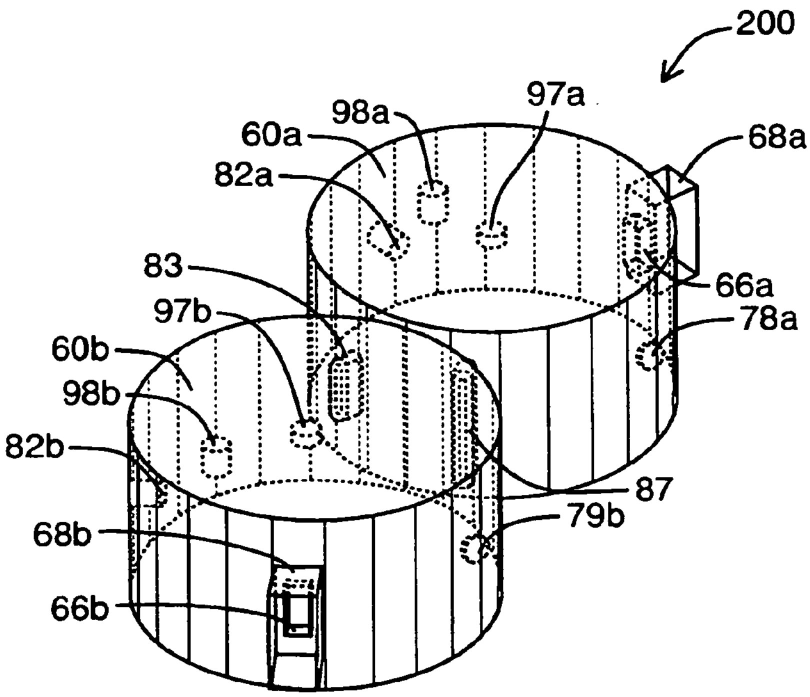

FIG. 14B

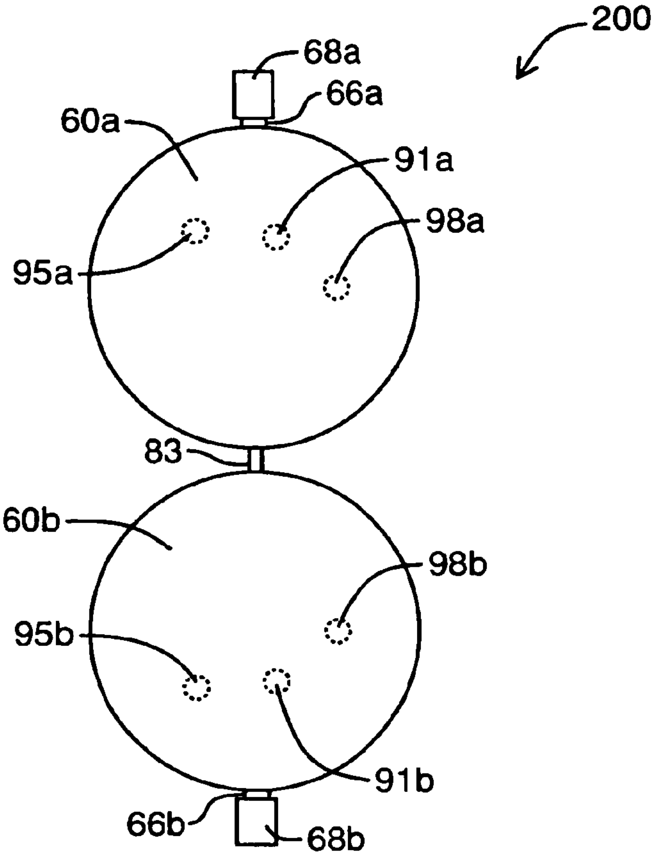

FIG. 15A

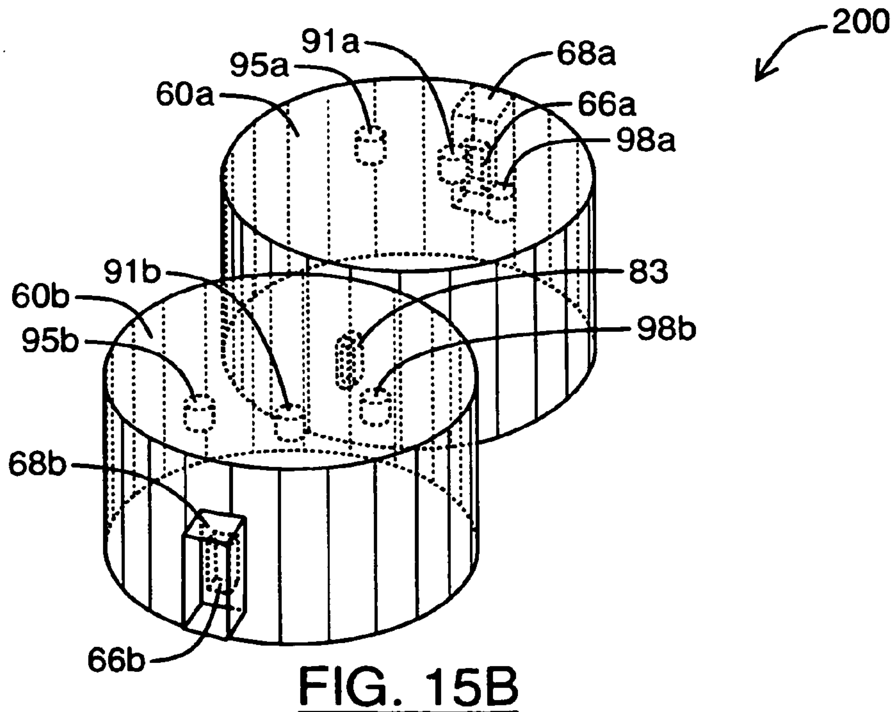

FIG. 15B

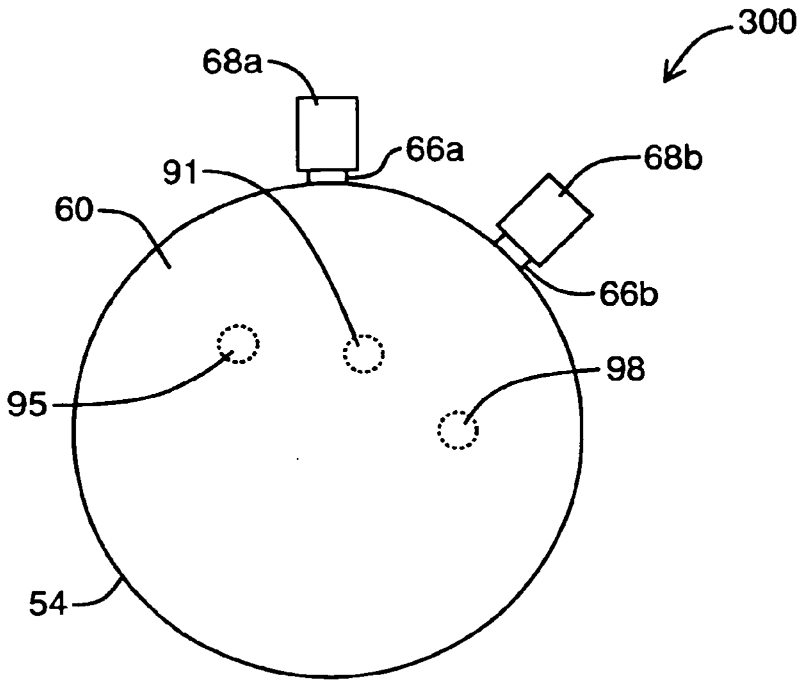

FIG. 16A

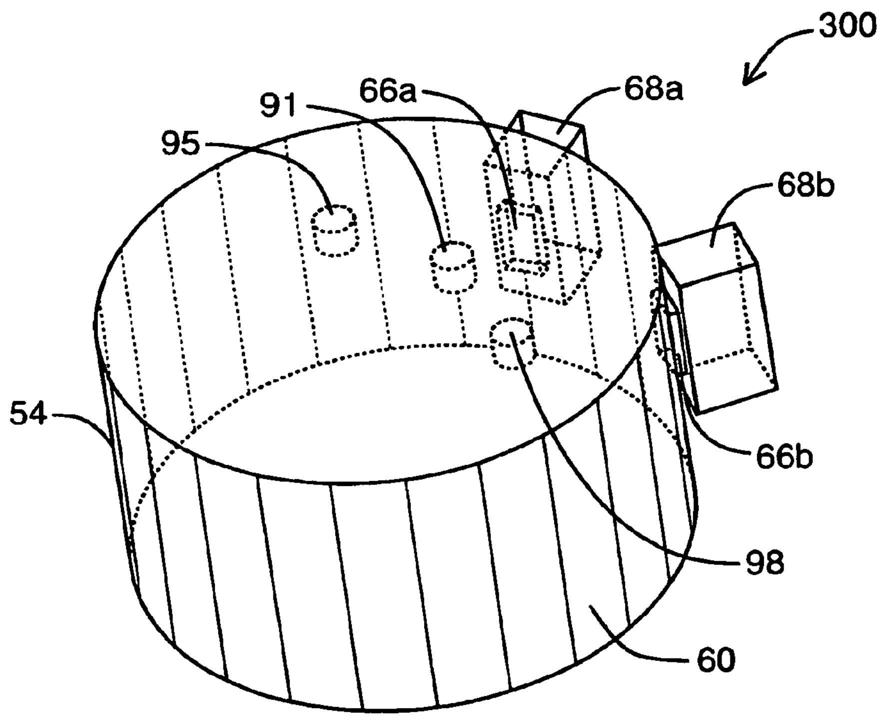

FIG. 16B

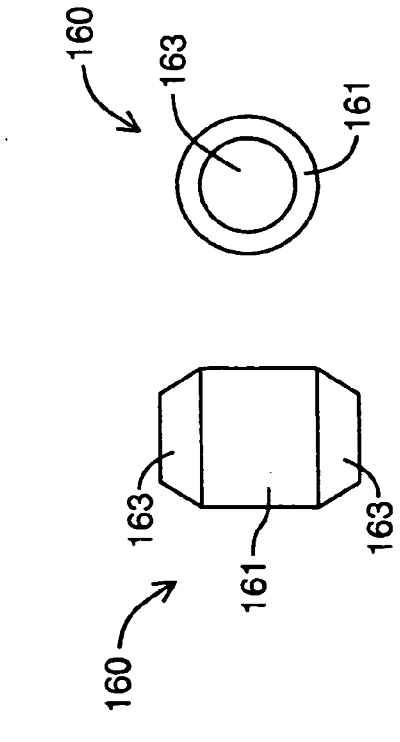

FIG. 17A

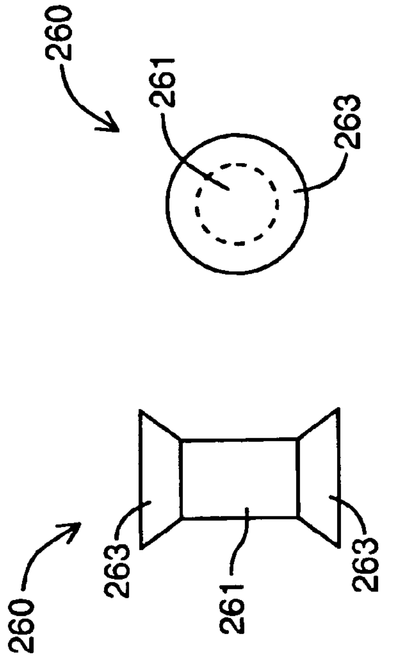

FIG. 17B

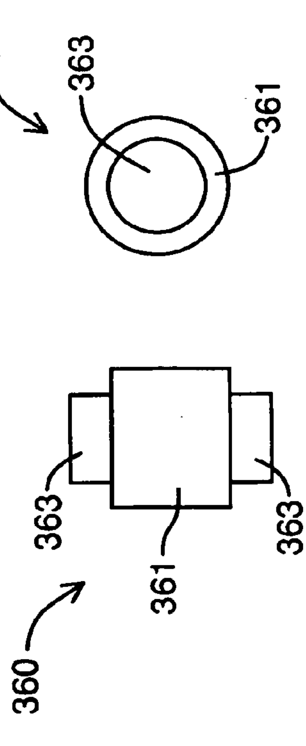

FIG. 17C

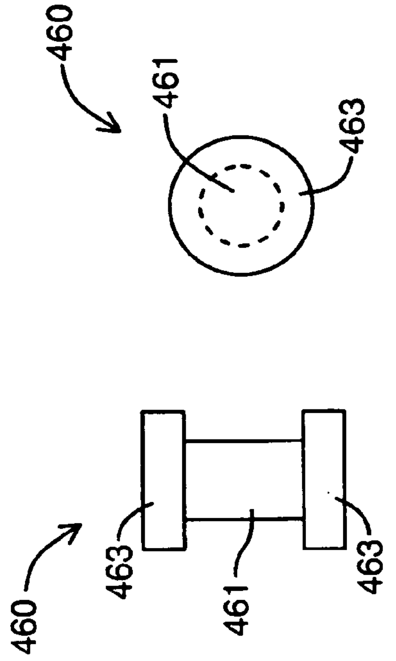

FIG. 17D

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 0250857 A **[0004]**
- EP 0751579 A **[0004]**
- WO 02093681 A **[0004]**