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**Reddy et al.**

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(54) **COUPLER FOR TUNING RESONANT CAVITIES**


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(73) Assignee: **Alcatel Lucent**, Paris (FR)



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(51) **Int. Cl.**

***H01P 1/20*** (2006.01)

***H01P 7/10*** (2006.01)

(52) **U.S. Cl.** ......................... **333/202**; 333/209; 333/235

(58) **Field of Classification Search** .................. 333/202, 333/209, 207, 212, 230, 219.1, 224, 235

See application file for complete search history.


(56) **References Cited**

U.S. PATENT DOCUMENTS


| | | | | |
|---|---|---|---|---|
| 5,070,313 | A * | 12/1991 | Gladh et al. | 333/202 |
| 5,777,534 | A * | 7/1998 | Harrison | 333/202 |
| 5,805,033 | A * | 9/1998 | Liang et al. | 333/202 |
| 6,304,160 | B1 * | 10/2001 | Loi et al. | 333/212 |
| 2004/0051602 | A1 | 3/2004 | Pance et al. | |
| 2008/0272861 | A1 | 11/2008 | Henault et al. | |

OTHER PUBLICATIONS

International Search Report dated Feb. 4, 2011 for corresponding PCT Application No. PCT/US2010/053746.

* cited by examiner


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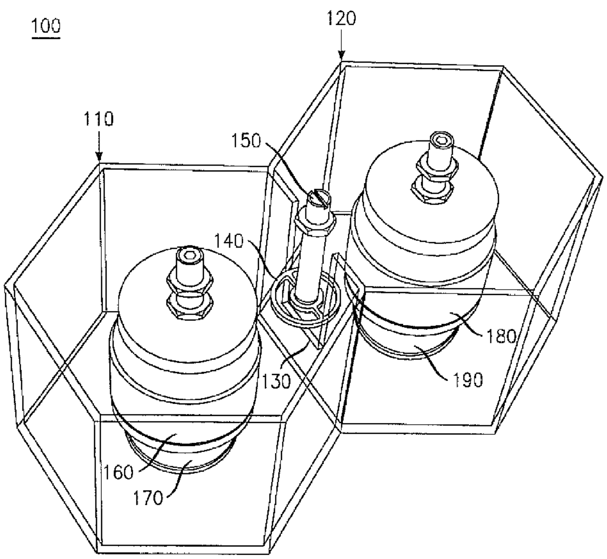
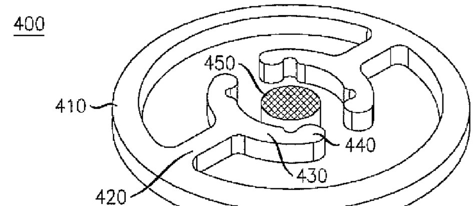
(57) **ABSTRACT**


Various exemplary embodiments relate to an improved coupler for resonant cavities and dielectric resonators. The coupler may permit accurate tuning of electromagnetic signals within desired frequency ranges. The coupler may be secured to a movable tuning device by a plurality of securing members. Each securing member may be separate, having no contact with any other securing member.


**20 Claims, 6 Drawing Sheets**



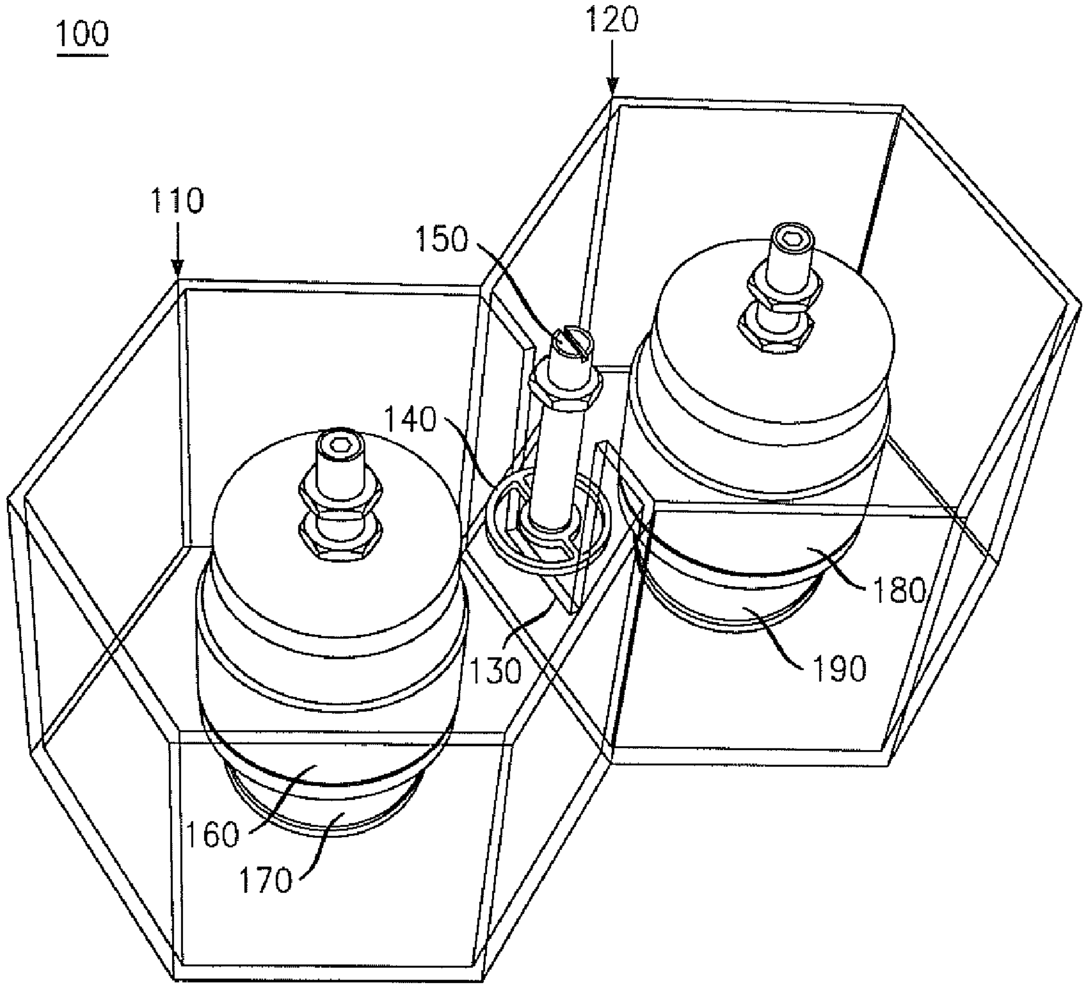



*FIG. 1*

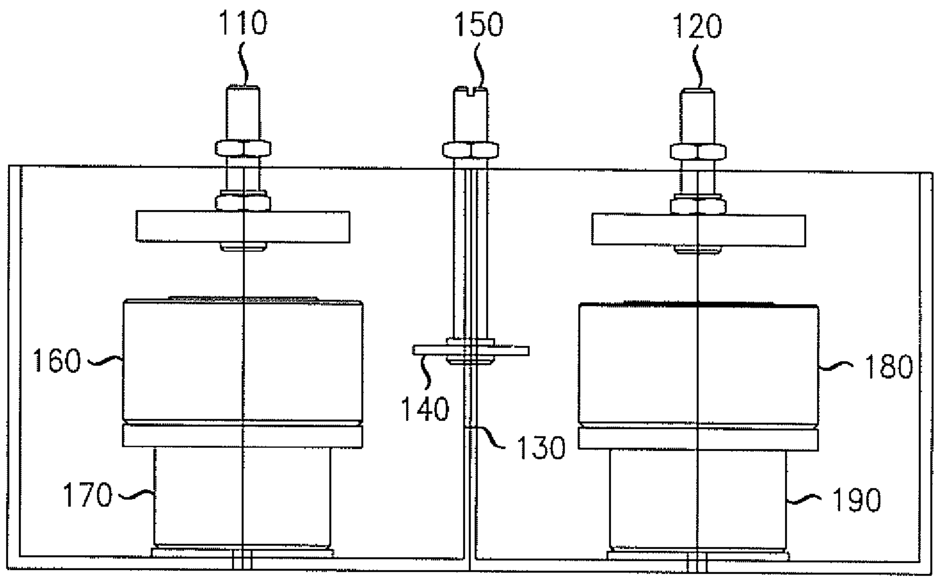



*FIG. 2*

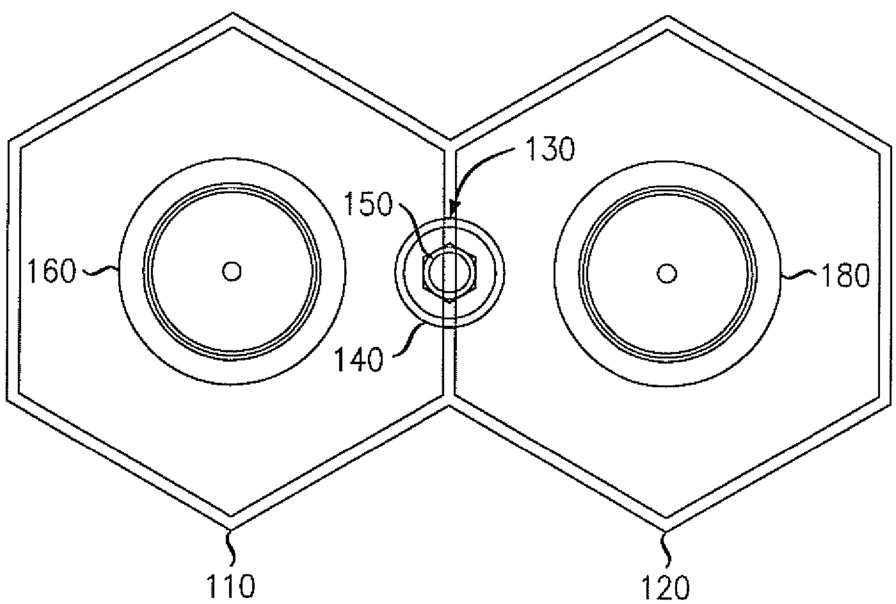



*FIG. 3*

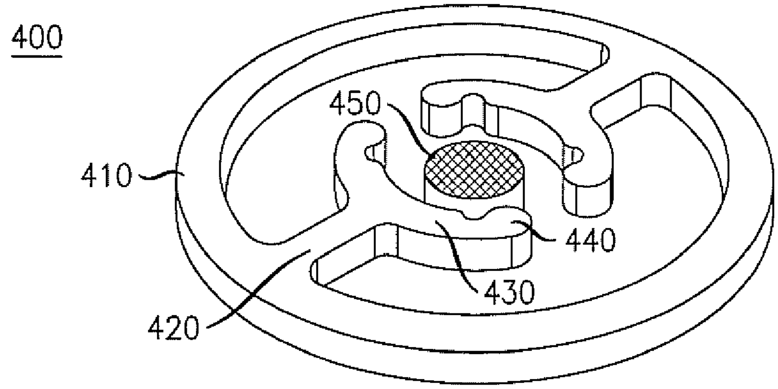



FIG. 4

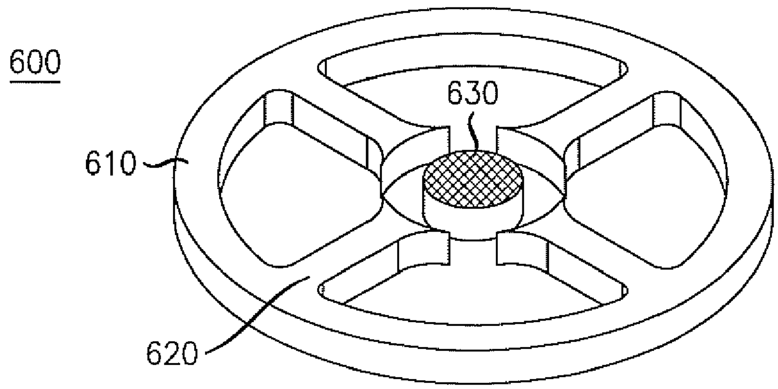



FIG. 6

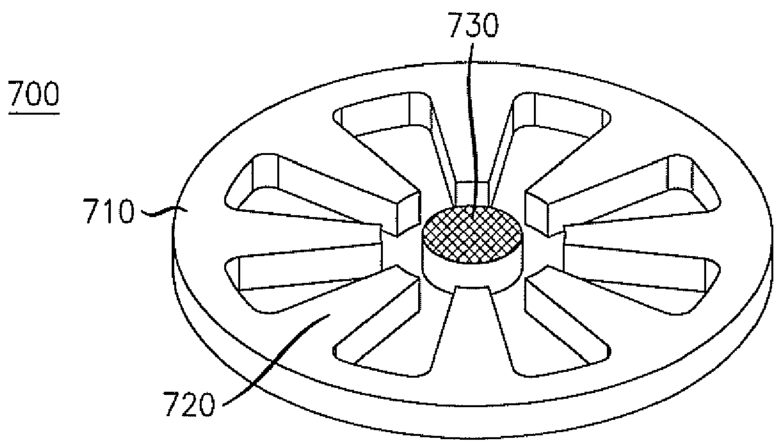



FIG. 7

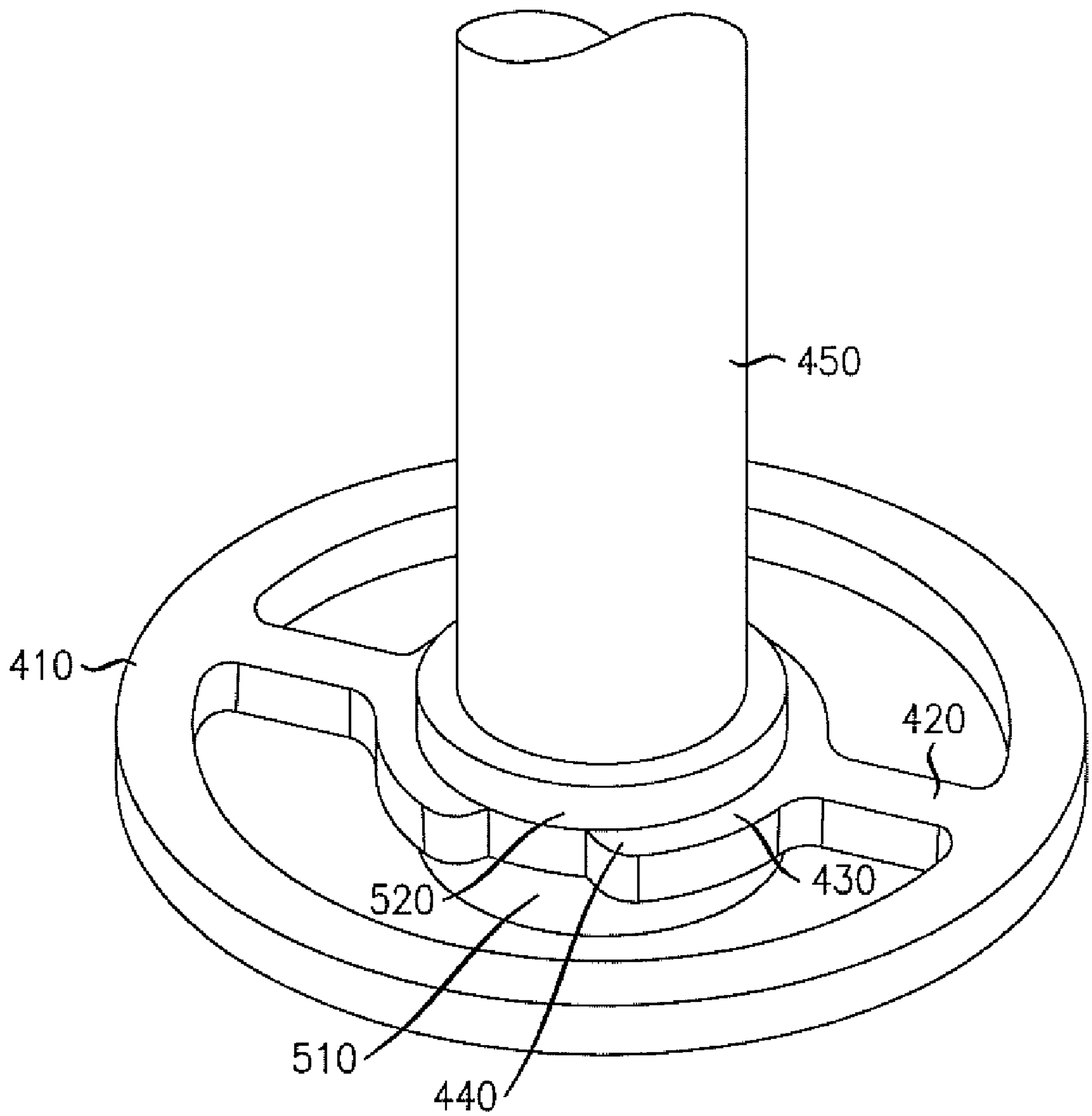



*FIG. 5*

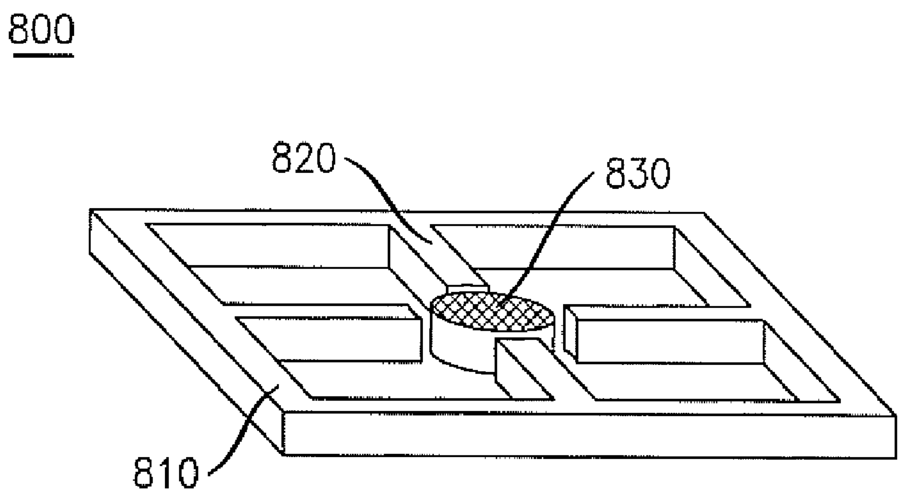



*FIG. 8*

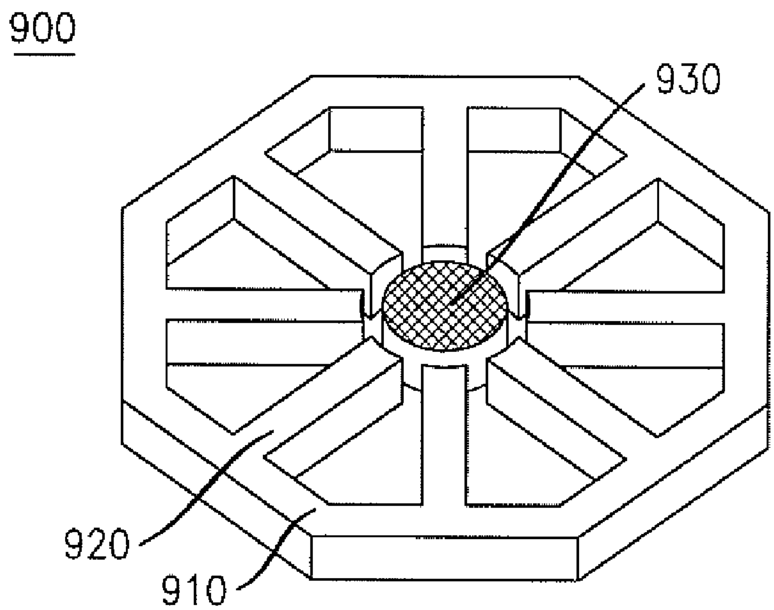



*FIG. 9*

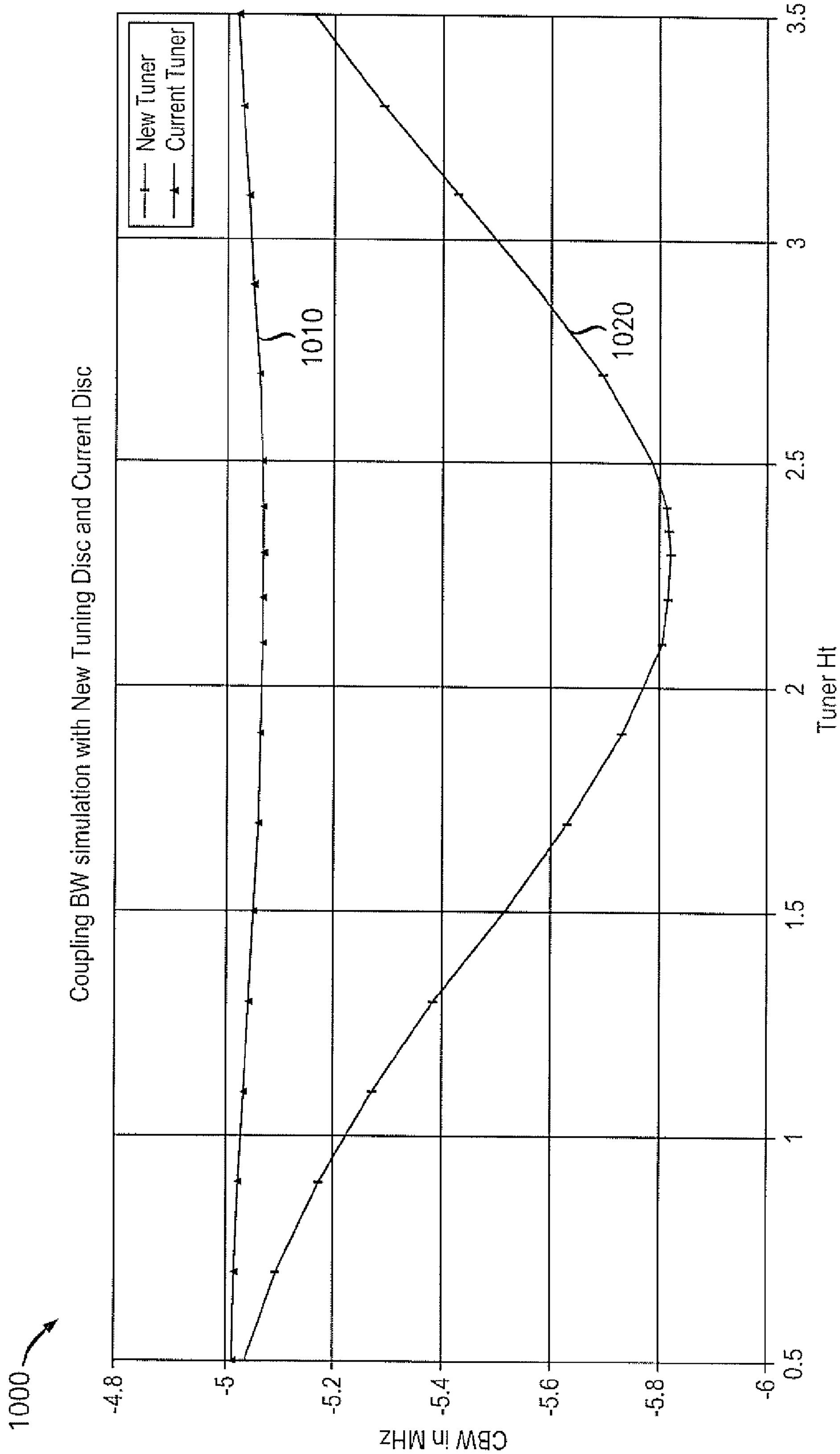

1000
Coupling BW simulation with New Tuning Disc and Current Disc
New Tuner
Current Tuner
1010
1020
-4.8
-5
-5.2
-5.4
-5.6
-5.8
-6
CBW in MHz
0.5
1
1.5
2
2.5
3
3.5
Tuner Ht

*FIG. 10*

# COUPLER FOR TUNING RESONANT CAVITIES

## TECHNICAL FIELD

Embodiments disclosed herein relate generally to a coupler for tuning frequency ranges between resonant cavities, such as dielectric resonators.

## BACKGROUND

A resonant cavity is a hollow volume that stores standing waves. In an electrical context, at least one conductive wall defines an outer surface of the resonant cavity. A probe in the middle of the volume may guide the waves in a desired manner. This probe, also known, as a "puck," may be metallic, ceramic, or made of other materials. The paragraphs below describe a resonant cavity that may include a ceramic puck, often called a "dielectric resonator."

A dielectric resonator is an electronic component that exhibits resonance for a narrow range of frequencies, generally in the microwave band. Resonators are used in, for example, radio frequency communication equipment. In order to achieve the desired operation, many resonators include a "puck" disposed in a central location within a cavity that has a large dielectric constant and a low dissipation factor.

The combination of the puck and the cavity imposes boundary conditions upon electromagnetic radiation within the cavity. The cavity has at least one conductive wall, which may be fabricated from a metallic material. A longitudinal axis of the puck may be disposed substantially perpendicular to an electromagnetic field within the cavity, thereby controlling resonation of the electromagnetic field.

When the puck is made of a dielectric material, such as ceramic, the cavity may resonate in the transverse electric (TE) mode. Thus, there may be no electric field in the direction of propagation of the electromagnetic field. While many TE modes may be used, dielectric resonators may use the TE011 mode for applications involving microwave frequencies. Using the TE011 mode as an exemplary case, the electric field will reach a maximum within the puck, have an azimuthal component along a central axis of the puck, generally decrease in the cavity away from the puck, and vanish entirely along any conductive cavity wall. The magnetic field will also reach a maximum within the puck, but will lack an azimuthal component.

When combining more than one dielectric resonator, a designer will need to couple electromagnetic energy from the first cavity to the second cavity. Such coupling may be difficult if the first cavity is distant from the second cavity. Coupling may also require the careful fabrication of apertures connecting the first and second cavities. These apertures may be tuned in a factory to compensate for manufacturing tolerances.

Despite such tuning, it may be difficult to build a filter that couples multiple cavities or dielectric resonators together to define a desired frequency range. Conventional attempts to provide specified spectra had been both impractical and expensive. These tuners have used many parts and tedious techniques that make it difficult to adjust coupling between resonant cavities or dielectric resonators.

Accordingly, there is a need for an improved coupler that provides tuning over a wide range of frequencies. More particularly, there is a need for a coupler that can be used in wide bandwidth filters. There is also a need for a cost effective technique that couples high dielectric resonators.

## SUMMARY

In light of the present need for improved tuning of resonant cavities and dielectric resonators, a brief summary of various exemplary embodiments is presented. Some simplifications and omissions may be made in the following summary, which is intended to highlight and introduce some aspects of the various exemplary embodiments, but not to limit the scope of the invention. Detailed descriptions of a preferred exemplary embodiment adequate to allow those of ordinary skill in the art to make and use the inventive concepts will follow in later sections.

In various exemplary embodiments, a system for enhanced tuning of dielectric resonators may comprise a first dielectric resonator that produces electromagnetic signals within a first range of frequencies; a second dielectric resonator that produces electromagnetic signals within a second range of frequencies; a movable tuning device disposed in an aperture between the first dielectric resonator and the second dielectric resonator; and a coupler secured to the movable tuning device. The coupler may transfer electromagnetic signals between the first dielectric resonator and the first dielectric resonator and comprise a plurality of securing members that extend radially inwardly toward the movable tuning device. Each of the securing members may be spaced apart from any other securing member.

In addition, in various exemplary embodiments, a system for enhanced tuning of electromagnetic signals in resonant cavities may comprise a movable tuning device disposed in an aperture between a first resonant cavity and a second resonant cavity, wherein a vertical axis of the movable tuning device is parallel to respective vertical axes of the first resonant cavity and the second resonant cavity; and a coupler secured to the movable tuning device. The coupler may transfer electromagnetic signals between the first resonant cavity and the second resonant cavity and comprise a plurality of securing members that extend radially inwardly toward the movable tuning device. Each of the securing members may be spaced apart from any other securing member.

Accordingly, various exemplary embodiments provide an improved way to couple electromagnetic energy between resonant cavities or dielectric resonators. These embodiments may allow precise tuning of frequencies to a desired spectral range. These embodiments may also allow a designer to obtain a wider tuning range than conventional tuning techniques.

## BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand various exemplary embodiments, reference is made to the accompanying drawings, wherein:

FIG. **1** shows a perspective view of an exemplary dielectric filter including an exemplary coupler;

FIG. **2** shows a side view of an exemplary dielectric filter including an exemplary coupler;

FIG. **3** shows a top view of an exemplary dielectric filter including an exemplary coupler;

FIG. **4** shows a first embodiment of an exemplary coupler;

FIG. **5** depicts a detailed view of an exemplary relationship between the coupler of the first embodiment and a movable tuning device;

FIG. **6** shows a second embodiment of an exemplary coupler;

FIG. 7 shows a third embodiment of an exemplary coupler;

FIG. 8 shows a fourth embodiment of an exemplary coupler;

FIG. 9 shows a fifth embodiment of an exemplary coupler; and

FIG. 10 depicts comparative test results for an exemplary coupler and a conventional aperture tuner.

## DETAILED DESCRIPTION

Referring now to the drawings, in which like numerals refer to like components or steps, there are disclosed broad aspects of various exemplary embodiments.

FIG. **1** is a perspective view of an exemplary dielectric filter **100**. As shown in FIG. **1**, filter **100** comprises a first dielectric resonator **110** and a second dielectric resonator **120**. An aperture **130** connects the first dielectric resonator **110** to the second dielectric resonator **120**. While exemplary filter **100** has only two dielectric resonators, one of ordinary skill in the art may design filter **100** to have an arbitrary number of dielectric resonators, depending upon the applicable environment for the filter.

FIG. **1** depicts first dielectric resonator **110** and second dielectric resonator **120** as hexagonal prisms. Thus, first dielectric resonator **110** and second dielectric resonator **120** are both semiregular polyhedra having eight faces. For hexagonal prisms, two of the eight faces are hexagonal while six of the eight faces are rectangular. It should be apparent, however, that one of ordinary skill in the art could design filter **100** to use dielectric resonators having other shapes. Alternative forms include, for example, spheres, cylinders, and cubes. Dielectric resonators may also have polyhedral shapes other than hexagonal prisms.

In each embodiment, at least one conductive wall may totally enclose the volume of first dielectric resonator **110** and second dielectric resonator **120**. The at least one conductive wall may be metallic. Thus, an appropriate stimulus could cause the enclosed volume to resonate, allowing first dielectric resonator **110** and second dielectric resonator **120** to become sources of electromagnetic oscillations. Aperture **130** would function as a tuner for these oscillations, thereby permitting filter **100** to generate electromagnetic signals within an appropriate frequency range.

The need for tuning is particularly acute when operation of the dielectric resonator should occur within a predefined range of frequencies. High power dielectric resonators may be widely used in applications, such as wireless broadcasting of video, audio, and other multimedia from a tower to a receiver. In current implementations in the United States, such technologies may transmit signals over a frequency spectrum of 716-722 MHz. Thus, a coupler **140** between first dielectric resonator **110** and second dielectric resonator **120** may provide accurate tuning within this spectral range. Exemplary couplers for use in filter **100** are described in further detail below in connection with FIGS. **4-9**.

FIG. **2** shows a side view of exemplary dielectric filter **100**. As detailed above, dielectric filter **100** may comprise a first dielectric resonator **110**, depicted on the left side, and a second dielectric resonator **120**, depicted on the right side. An aperture **130** may couple electromagnetic signals between first dielectric resonator **110** and second dielectric resonator **120**. A movable tuning device **150** located within aperture **130** may move up and down along a vertical axis. This vertical axis may be parallel to respective vertical axes in both first dielectric resonator **110** and a second dielectric resonator **120**. Movable tuning device **150** may be a screw or rod, for example. As illustrated in FIG. **2**, tuning device **150** may include a standard head, such that a tuning tool (e.g., a screwdriver) may be used to rotate tuning device **150**, thereby moving tuning device **150** vertically within the filter **100**.

Coupler **140** may be attached or otherwise coupled to the end of tuning device **150**, such that coupler **140** also moves vertically within the filter. An exemplary arrangement for attaching coupler **140** to tuning device **150** is described in further detail below in connection with FIG. **5**.

First dielectric resonator **110** may comprise a puck **160** and a support **170**. Second dielectric resonator **120** may comprise a puck **180** and a support **190**. Puck **160** and puck **180** may define horizontal axes that are perpendicular to the vertical axis of movable tuning device **150**.

FIG. **3** shows a top view of exemplary dielectric filter **100**. As detailed above, dielectric filter **100** may comprise a first dielectric resonator **110**, on the left, and a second dielectric resonator **120**, on the right. An aperture **130** may couple electromagnetic signals between first dielectric resonator **110** and second dielectric resonator **120**. A coupler **140** located within aperture **130** may tune the electromagnetic signals to define a spectral range of desired frequencies, such as 716-722 MHz. Coupler **140** may be secured to movable tuning device **150**. Various ways to secure coupler **140** to movable tuning device **150** are depicted in FIG. **4** through FIG. **8**.

FIG. **4** shows a first embodiment of an exemplary coupler **400**. Coupler **400** may comprise an outer member **410** that is concentric relative to the movable tuning device **450**, wherein a diameter of outer member **410** is proportional to a tuning range for the electromagnetic signals. Outer member **410** may be toroidal in shape, having an annular form relative to a central axis. Outer member **410** may have a circular or rectangular cross-section.

A pair of securing members **420** may extend radially inwardly from outer member **410** toward movable tuning device **450**. The securing members **420** may be opposite to each other and are spaced apart from one another. Because securing members **420** are entirely separate, having no physical contact, the size of outer member **410** may determine the overall coupling behavior of coupler **400**.

Clamping members **430** hold the securing members **420** against the movable tuning device. Each clamping member **430** may comprise a pair of prongs **440**. The prongs **440** secure the coupler **400** to the movable tuning device **450**, but prongs **440** of different securing members do not touch. Consequently, only the diameter of toroidal member **410** will influence the transfer of electromagnetic energy across coupler **400**.

FIG. **5** depicts a detailed view of an exemplary relationship between coupler **400** and movable tuning device **450**. Coupler **400** may be placed on movable tuning device **450** by sliding down until coupler **400** reaches stopping member **510**. Stopping member **510** may be a screw head, washer, or another appropriate barrier. Holding member **520** may be a disk disposed above coupler **400**, maintaining the relative position of coupler **400** on movable tuning device **450**. Holding member **520** may be an epoxy disk, wafer, or other item fabricated from a non-conductive material.

FIG. **6** shows a second embodiment of an exemplary coupler **600**. Coupler **600** may comprise an outer member **610** that may be concentric relative to a movable tuning device **630**, wherein a width of outer member **610** may be proportional to a tuning range for the electromagnetic signals. A quartet of securing members **620** may extend radially inwardly toward the movable tuning device **530**. Alternatively, other numbers of securing members **620** may be used. In various exemplary embodiments, the securing members

620 do not touch and may be spaced roughly 90° apart. Alternatively, spacing may be irregular instead of occurring at identical intervals.

FIG. **7** shows a third embodiment of an exemplary coupler **700**. Coupler **700** may comprise an outer member **710** that may be concentric relative to movable tuning device **730**, wherein a diameter of outer member **710** may be proportional to a tuning range for the electromagnetic signals. An octet of securing members **720** may extend radially inwardly toward movable tuning device **730**. Alternatively, other numbers of securing members **720** may be used. In various exemplary embodiments, the securing members **720** do not touch and may be spaced roughly 45° apart. Alternatively, spacing may be irregular instead of occurring at identical intervals.

FIG. **8** shows a fourth embodiment of an exemplary coupler **800**. Coupler **800** may comprise an outer member **810** that may be concentric relative to movable tuning device **830**, wherein an external surface of outer member **810** may be hexahedral in shape. Outer member **810** may have a square cross-section in order to promote uniform tuning. A quartet of securing members **820** may extend radially inwardly toward movable tuning device **830**. Alternatively, other numbers of securing members **820** may be used. In various exemplary embodiments, the securing members **820** do not touch and may be spaced roughly 90° apart. Alternatively, spacing may be irregular instead of occurring at identical intervals.

FIG. **9** shows a fifth embodiment of an exemplary coupler **900**. Coupler **900** may comprise an outer member **910** that may be concentric relative to movable tuning device **930**, wherein an external surface of outer member **910** may be octagonally-prismatic in shape. An octet of securing members **920** may extend radially inwardly toward movable tuning device **930**. Alternatively, other numbers of securing members **920** may be used. In various exemplary embodiments, the securing members **920** do not touch and may be spaced roughly 45° apart. Alternatively, spacing may be irregular instead of occurring at identical intervals. Other polyhedral shapes may be used for outer member **910**, depending upon the tuning environment of the aperture containing coupler **900**.

It should be apparent that the exemplary embodiments of the coupler described above in connection with FIGS. **4-9** may be combined in a number of ways. For example, the outer members of a particular embodiment may be combined with the securing members of any other embodiment. Other suitable shapes for the outer member of the coupler and the securing members will be apparent to those of skill in the art.

FIG. **10** depicts comparative test results **1000** for an exemplary coupler and a conventional aperture tuner. In particular, FIG. **10** presents a graph of coupling tunability for a particular frequency range. For test results **1000**, the x-axis depicts the distance of a movable tuning device in inches relative to at least one conductive wall of the cavity. The y-axis depicts the coupling bandwidth in MHz.

For a conventional aperture tuner, a tuning range is very narrow. This range may, for example, extend from 5% to 8%, a range that is insufficient for many applications. As shown in FIG. **10**, test results **1010** for the conventional tuner reflect only a slight variation from a value of roughly 5 MHz.

For an exemplary tuner using a coupler, as described above in FIG. **4** through FIG. **9**, test results **1020** may be greatly improved compared to test results **1010**. Test results **1020** may follow a Gaussian distribution, a bell-shaped curve that reaches a level of roughly 5.8 MHz at a tuner height of about 2.3 inches. This distribution may result in 25% tunability in the coupling band, thereby providing the flexibility to use resonant cavities and dielectric resonators in new applications.

Although the various exemplary embodiments have been described in detail with particular reference to certain exemplary aspects thereof, it should be understood that the invention is capable of other embodiments and its details are capable of modifications in various obvious respects. As is readily apparent to those skilled in the art, variations and modifications can be affected while remaining within the spirit and scope of the invention. Accordingly, the foregoing disclosure, description, and figures are for illustrative purposes only and do not in any way limit the invention, which is defined only by the claims.

What is claimed is:

**1**. A system for enhanced tuning of dielectric resonators, the system comprising:
- a first dielectric resonator that produces electromagnetic signals within a first range of frequencies;
- a second dielectric resonator that produces electromagnetic signals within a second range of frequencies;
- a movable tuning device disposed in an aperture between the first dielectric resonator and the second dielectric resonator; and
- a coupler secured to the movable tuning device, wherein the coupler transfers electromagnetic signals between the first dielectric resonator and the first dielectric resonator and comprises a plurality of securing members that extend radially inwardly toward the movable tuning device to secure the coupler to the movable tuning device, each of the securing members being spaced apart from all other securing members.

**2**. The system of claim **1**, wherein the coupler further comprises:
- an outer member that is concentric relative to the movable tuning device, wherein a width of the outer member is proportional to a tuning range for the electromagnetic signals in the aperture.

**3**. The system of claim **2**, wherein the coupler further comprises:
- clamping members that hold the plurality of securing members against the movable tuning device.

**4**. The system of claim **3**, wherein each clamping member comprises a pair of prongs, wherein the pair of prongs secures the coupler to the movable tuning device.

**5**. The system of claim **2**, wherein the plurality of securing members comprise at least four securing members that extend radially inwardly from the outer member toward the movable tuning device.

**6**. The system of claim **2**, wherein the plurality of non-contiguous securing members comprise at least eight securing members that extend radially inwardly from the outer member toward the movable tuning device.

**7**. The system of claim **1**, wherein the coupler further comprises:
- an outer member that is concentric relative to the movable tuning device, wherein an external surface of the outer member is hexahedral in shape.

**8**. The system of claim **7**, wherein the plurality of securing members comprise at least four securing members that extend inwardly from the outer member toward the movable tuning device.

**9**. The system of claim **1**, wherein the coupler further comprises:
- an outer member that is concentric relative to the movable tuning device, wherein an external surface of the outer member is octagonally prismatic in shape.

**10**. The system of claim **9**, wherein the plurality of securing members comprise at least eight securing members that extend inwardly from the outer member toward the movable tuning device.

**11**. A system for enhanced tuning of electromagnetic signals in resonant cavities, the system comprising:

a movable tuning device for placement in an aperture between a first resonant cavity and a second resonant cavity, wherein a vertical axis of the movable tuning device is parallel to respective vertical axes of the first resonant cavity and the second resonant cavity; and

a coupler secured to the movable tuning device, wherein the coupler transfers electromagnetic signals between the first resonant cavity and the second resonant cavity and comprises a plurality of securing members that extend radially inwardly toward the movable tuning device to secure the coupler to the movable tuning device, each of the securing members being spaced apart from all other securing members.

**12**. The system of claim **11**, wherein the coupler further comprises:

an outer member that is concentric relative to the movable tuning device, wherein a width of the outer member is proportional to a tuning range for the electromagnetic signals in the aperture.

**13**. The system of claim **12**, wherein the coupler further comprises:

clamping members that hold the plurality of securing members against the movable tuning device.

**14**. The system of claim **13**, wherein each clamping member comprises a pair of prongs, wherein the pair of prongs secures the coupler to the movable tuning device.

**15**. The system of claim **12**, wherein the plurality of securing members comprise at least four securing members that extend radially inwardly from the outer member toward the movable tuning device.

**16**. The system of claim **12**, wherein the plurality of securing members comprise at least eight securing members that extend radially inwardly from the outer member toward the movable tuning device.

**17**. The system of claim **11**, wherein the coupler further comprises:

an outer member that is concentric relative to the movable tuning device, wherein an external surface of the outer member is hexahedral in shape.

**18**. The system of claim **17**, wherein the plurality of securing members comprise at least four securing members that extend inwardly from the outer member toward the movable tuning device.

**19**. The system of claim **11**, wherein the coupler further comprises:

an outer member that is concentric relative to the movable tuning device, wherein an external surface of the outer member is octagonally prismatic in shape.

**20**. The system of claim **19**, wherein the plurality of securing members comprise at least eight securing members that extend inwardly from the outer member toward the movable tuning device.

* * * * *