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(54) WAVEGUIDE FILTER

(57) Problem

In prior-art high-frequency filters, to compensate for manufacturing tolerance, it is common practice to tune the filter using tuning elements such as threaded screws made of metal or various combinations of metal and plastics. Resonator casings made of aluminum require interference threads for receiving the corresponding tuning elements since aluminum is too soft for fine threads.

Further, contamination of the aluminum used as raw material - such as by ferrite, nickel, steel or other ferromagnetic material - causes the casing to exhibit hysteresis when exposed to reversing magnetic fields, thus resulting in undesired passive intermodulation. Avoiding this intermodulation imposes a high degree of purity on the raw material employed, which in turn increases the unit cost of a filter manufactured from such material.

Solution

The problem is solved by a waveguide filter having a casing of material transparent to light of a designated lasing wavelength, the casing bearing an electrically conductive internal plating such that the casing defines a radio-frequency cavity, and dielectric resonators protruding into the cavity, the resonators being dimensioned such as to exhibit a given resonant frequency.

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Description

Technical Field

[0001] The invention relates to waveguide filters.

Background Art

[0002] In electrical and communications engineering, by waveguide filter is meant any electronic filter that is based on electromagnetic waveguides. Waveguide filters are a basic component of electronic engineering designs and have numerous applications such as the selection of signals and limitation of noise. State-of-the-art waveguide filters are mostly employed in the radio and especially microwave spectrum due to their convenient size and low loss. Examples of known designs are given in JARRY, Pierre, et al. Advanced design techniques and realizations of microwave and RF filters. Hoboken, New Jersey: John Wiley, 2008. ISBN 0470183101.

[0003] There are many applications of filters whose design objectives reach beyond rejection or passing of certain frequencies. Amongst the more common applications of this kind are impedance matching networks, directional couplers, power dividers, power combiners, and diplexers. Other known applications include multiplexers, de-multiplexers, negative-resistance amplifiers, and time-delay networks, all of which shall be encompassed by the term "waveguide filter" as employed hereinafter.

[0004] Practical waveguide filters typically exhibit some amount of passive intermodulation (PIM), that is, amplitude modulation in signals that contain two or more different frequencies. While these distortions may cause a telecommunication signal to interfere with adjacent channels and impede reception, they pose a severe problem in measurement and test instrumentation. This phenomenon is elucidated in VICENTE, Carlos, et al. Passive Intermodulation Characteristics. IEEE trans. microwave theor. tech.. 08 August 2005, vol.53, no.8, p.2515 - 2525.

[0005] To minimize such undesired effect, EP 2656435 A (KATHREIN WERKE KG [DE]) 30.10.2013 proposes a high-frequency filter in coaxial design which allows a simple option for tuning resonators contained in the high-frequency filter.

Summary of invention

[0006] The invention aims to provide an improved waveguide filter.

Technical Problem

[0007] In prior-art high-frequency filters, to compensate for manufacturing tolerance, it is common practice to tune the filter using tuning elements such as threaded screws made of metal or various combinations of metal and plastics. Resonator casings made of aluminum require interference threads for receiving the corresponding tuning elements since aluminum is too soft for fine threads.

[0008] Further, contamination of the aluminum used as raw material - such as by ferrite, nickel, steel or other ferromagnetic material - causes the casing to exhibit hysteresis when exposed to reversing magnetic fields, thus resulting in undesired passive intermodulation. Avoiding this intermodulation imposes a high degree of purity on the raw material employed, which in turn increases the unit cost of a filter manufactured from such material.

Solution to Problem

[0009] The problem is solved by the characterizing features of the independent claims.

Advantageous effect of invention

[0010] The invention provides for a highly accurate filter ideally suited for measuring and testing purposes. The proposed filter may also be used in the mass market, where demand for wireless broadband has soared due to technological innovations such as third-generation (3G) and fourth-generation (4G) mobile services as well as the rapid expansion of wireless Internet services. Here, a bandpass according to the invention enables broadcast licensees to tap the full potential of their allocated portion of the radio frequency (RF) spectrum, bidding for which requires staggering investments in many countries.

[0011] The application of a transparent housing material enables the inventive use of laser ablation for tuning the filter while preserving the imperviousness of the casing. In contrast to the ubiquitous "tuning screws" of conventional high-frequency filters, this fundamental modification allows the design of an airproof device that is fully sealed against intrusion by dust or liquids and thus protected from corrosion. Such apparatus operates reliably in harsh usage environments and under circumstances such as strong vibrations, extreme temperatures, and wet or dusty atmosphere, all of which are customary operating conditions for base stations in the context of mobile telephony, wireless computer networking, and other wireless communications. To eliminate any remaining risk of contaminant entering the casing through conductor inlets or outlets, the inward-facing and outward-facing conductor of each port may be galvanically isolated by means of inductive or capacitive coupling.

[0012] Considering the scarcity of high-grade aluminum and its consequent purchase price, the invention also allows for a considerable reduction in unit cost. Specifically, the substitution of aluminum by an amorphous solid potentially renders performance of the filter independent from the purity of the starting material. As a preferred embodiment, a filter encased in glass proves extremely durable under most conditions, erodes very slowly, and withstands the action of water.

[0013] The particle density of undesirable atoms and molecules inside the filter housing may be reduced by casting or molding the casing in a vacuum chamber such that the vacuum prevails in the resulting cavity. This way, its inside may be plated by means of vacuum deposition, thus yielding a plating of higher quality and more uniform thickness than would typically be achieved under atmospheric pressure.

[0014] For the unlikely case of residual moisture remaining inside the casing, resistance against corrosion and oxidation may nevertheless be retained by employing a noble metal for the conductive internal plating that is required to confine the electromagnetic field. As a base layer, silver is particularly preferred for its high electrical conductivity. Due to its malleability, ductility, and resistance to corrosion or other chemical reactions, a gold coating may optionally be superimposed. Resistance to chemical attack, excellent high-temperature characteristics, and stable electrical properties are also found in a surface layer of a platinum-group metal such as palladium, the latter being particularly preferred for its low density and melting point.

Description of embodiments

[0015] A bandpass is manufactured from a set of coaxially aligned ceramic resonators. In a vacuum chamber, these are cast into a glass casing together with at least two pairs of inward-facing and outward-facing conductors designated as input and output ports. The cast is configured such that the resonators protrude into the cavity defined by their casing.

[0016] Once the glass has cured, each resonator is trimmed by laser ablation from outside the casing while measuring resonant frequency. This tuning process may be continued arbitrarily until the filter exhibits its designated frequency profile.

[0017] In a final step, a predetermined amount of silver is vaporized within the evacuated cavity and deposits on its inner surface as an internal plating. This silver base layer may optionally be replaced or superimposed by a layer of gold or palladium, effectively rendering the cavity impermeable to electromagnetic waves.

Industrial applicability

[0018] The invention may be applied, inter alia, throughout the telephone networks, satellite communications, and television broadcasting industries.

Citation list

[0019] The following literature is cited throughout this document.

Patent literature

[0020] EP 2656435 A (KATHREIN WERKE KG [DE]) 30.10.2013

Non-patent literature

[0021] JARRY, Pierre, et al. Advanced design techniques and realizations of microwave and RF filters. Hoboken, New Jersey: John Wiley, 2008. ISBN 0470183101.

[0022] VICENTE, Carlos, et al. Passive Intermodulation Characteristics. IEEE trans. microwave theor. tech.. 08 August 2005, vol.53, no.8, p.2515 - 2525.

Claims

1. Waveguide filter
characterized in
a casing of material transparent to light of a designated lasing wavelength, the casing bearing an electrically conductive internal plating such that the casing defines a radio-frequency cavity,
and
dielectric resonators protruding into the cavity, the resonators being
dimensioned such as to exhibit a given resonant frequency.

2. Filter as in Claim 1
wherein
the material is an amorphous solid.

3. Filter as in Claim 2
wherein
the solid is glass.

4. Filter as in any of the preceding claims
wherein
a vacuum prevails within the cavity.

5. Filter as in any of the preceding claims
having
an inward-facing and an outward-facing conductor, wherein the conductors are mutually inductively or capacitively coupled.

6. Filter as in any of the preceding claims
wherein
the plating consists of noble metal.

7. Filter as in Claim 6
wherein
the plating comprises a base layer of silver.

8. Filter as in Claim 7
wherein
the plating comprises a surface layer of gold.

9. Filter as in Claim 7

wherein
the plating comprises a surface layer of a platinum-group metal, especially palladium.

10. Filter as in any of the preceding claims
wherein
the filter takes the form of a bandpass.

11. Process for the manufacture of a filter according to any of the
preceding claims,
characterized in
encasing the resonators such that the resonators protrude into the cavity defined by the casing,
while measuring resonant frequency, laser-ablating each resonator at the designated wavelength until the resonant frequency meets a given value, and applying the internal plating to the casing.

12. Process as in Claim 11
wherein
the encasing is effectuated by casting.

13. Process as in Claim 12
wherein
the casting is performed in a vacuum chamber.

14. Process as in Claim 13
wherein
the plating is applied by vacuum deposition.

15. Use of a filter according to any of Claim 1 to Claim 10.

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EUROPEAN SEARCH REPORT

Application Number
EP 17 16 1989

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/219013 A1 (KUMAR PAVAN [CA] ET AL) 6 October 2005 (2005-10-06) * paragraphs [0002], [0021] - paragraph [0042]; figure 1 *	1-3, 6-10,15	INV. H01P1/208 H01P11/00
X Y	US 5 329 687 A (SCOTT RICHARD D [US] ET AL) 19 July 1994 (1994-07-19) * column 3 - column 5; figures 2, 3A *	1,2,4-7, 10,15 14	
X	US 2003/234695 A1 (HARUTA KAZUMASA [JP] ET AL) 25 December 2003 (2003-12-25) * paragraph [0031] - paragraph [0037]; figure 1 *	1,10,11, 15	
X Y	US 2003/048148 A1 (HUMPHREYS RICHARD G [GB] ET AL) 13 March 2003 (2003-03-13) * paragraph [0049] - paragraph [0059]; figures 4(a), 4(b) * * paragraph [0066] - paragraph [0067]; figures 7(a), 7(b) *	1,11-13 14	
A	US 7 148 762 B2 (BOSCH GMBH ROBERT [DE]) 12 December 2006 (2006-12-12) * column 2 - column 3; figures 1, 2, 4 *	11	TECHNICAL FIELDS SEARCHED (IPC) H01P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 September 2017	Hueso González, J

CATEGORY OF CITED DOCUMENTS

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

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

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 1989

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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18-09-2017

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US 2003234695 A1	25-12-2003	EP 1376738 A1	02-01-2004
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP 2656435 A **[0005] [0020]**

Non-patent literature cited in the description

- **JARRY, PIERRE et al.** Advanced design techniques and realizations of microwave and RF filters. John Wiley, 2008 **[0002] [0021]**
- **VICENTE, CARLOS et al.** Passive Intermodulation Characteristics. *IEEE trans. microwave theor. tech.,* 08 August 2005, vol. 53 (8), 2515-2525 **[0004] [0022]**