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(54) Second harmonic spurious mode suppression in half-wave resonators, with application to microwave filtering structures

(57) The invention relates to an half-wave resonator providing reduced second armonic spurious mode, the resonator comprises a $\lambda/2$-length microstrip conductor, where λ is the line wavelength correspondent to the fundamental resonance frequency and is characterized in that it further comprises means for forcing a low voltage in the middle of the $\lambda/2$-length microstrip conductor. Advantageously, such means for forcing a low voltage comprise a low impedance, wide-band resistor. The invention further includes a band filter and a method for providing reduced second armonic spurious mode in a half-wave resonator.

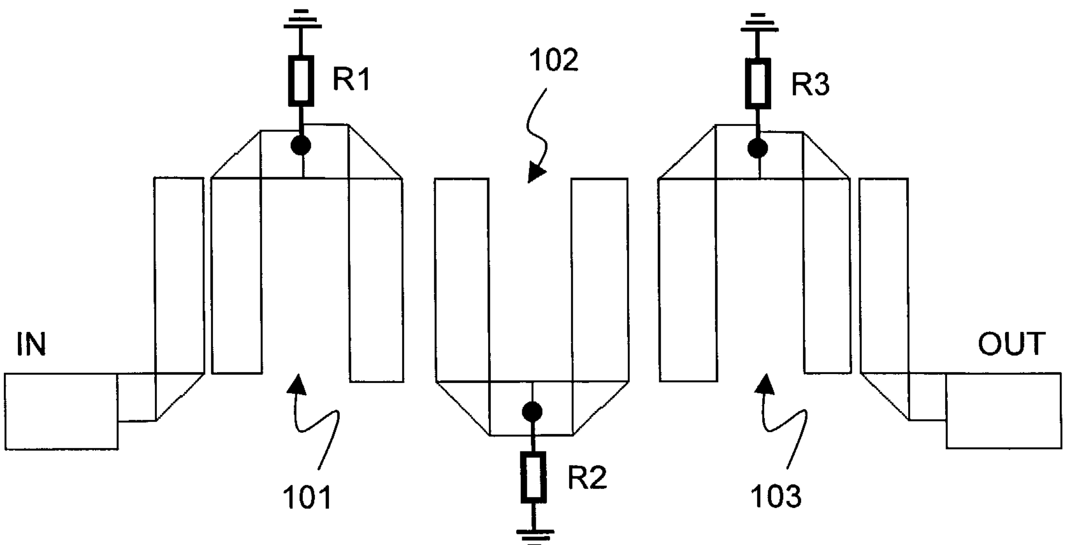

Fig. 3

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Description

[0001] The present invention relates to resonators and a method for suppressing second harmonic spurious mode in half-wave resonators. The present invention also relates to microwave band filtering structures and a method for microwave band filtering signals.

[0002] Electromagnetic resonators are often used in filters in order to pass or reject certain signal frequencies. To optimize filter performance, the resonators should have a minimum of signal loss in the passed frequency range.

[0003] Resonators like those employed for instance in microwave filters (edge-coupled, hairpin, etc.) give rise to spurious responses at frequencies well above the normally operating ones. These responses can take place with little attenuation, so that undesired signals (like for instance second and third harmonics) may pass through the filter with an excessive level, which is often unacceptable to the rest of RF system.

[0004] In case of half-wave resonators, the first spurious mode occurs typically at frequencies which are twice the bandpass ones, namely when the resonator length is equal to an entire wavelength, and the next spurious mode takes place (with lower theoretical transmission loss) at three times the first resonance.

[0005] A typical solution for solving the above problem comprises the step of placing an extra filter (typically a lowpass one) in series with the bandpass structure, the extra filter being designed in order to avoid the above "reentrance" problems, which attenuates the spurious responses of the bandpass filter.

[0006] The extra filter arrangement is rather effective but it requires an extra amount of space. Furthermore, the extra filter will dissipate some RF energy.

[0007] In view of the above drawbacks of known solutions, the main object of the present invention is providing a resonator arrangement wherein second harmonic spurious mode is suppressed, in particular a resonator arrangement to be used in microwave filtering structures.

[0008] A further object of the present invention is providing a method for suppressing second harmonic spurious mode in half-wave resonators, in particular in half-wave resonators to be used in microwave filtering structures.

[0009] A still further object of the present invention is providing a microwave band filter wherein second harmonic spurious mode is suppressed.

[0010] A still further object of the present invention is providing a method for microwave band filtering signals.

[0011] The above and further objects of the present invention are obtained by a half-wave resonator according to claim 1, a method for suppressing second harmonic spurious mode in half-wave resonators according to claim 3, a microwave band filter according to claim 8 and a method for microwave band filtering signals according to claim 10. Further advantageous characteristic of the present invention are set forth in respective dependent claims. All the claims are intended to be an integral part of the present description.

[0012] The basic idea of the present invention, mainly oriented to microstrip or stripline technologies, consists in rejecting the second resonant response by "forcing" a low voltage in the middle of the half wavelength resonator, where a voltage null would occur under normal operating conditions.

[0013] The present invention will become clear after reading the attached below description, given by way of non limiting example, to be read making reference to the attached sheets of drawings, wherein:

Fig. 1 shows first, second and third resonances in a $\lambda/2$ transmission line;
Fig. 2 shows a third order hairpin bandpass filter layout according to the state of the art;
Fig. 3 shows the filter layout of Fig. 2 with second resonance suppressing resistors according to the present invention;
Fig. 4 shows a 10 GHz hairpin filter response (with n = 3), without and with the present invention (spurious responses);
Fig. 5 shows a third order edge-coupled filter layout according to the state of the art;
Fig. 6 shows the filter layout of Fig. 5 with second resonance suppressing resistors according to the present invention;
Fig. 7 shows a 10 GHz edge-coupled filter response without and with the present invention (spurious responses); and
Fig. 8 shows a possible example of practical implementation in case of microstrip edge-coupled structure.

[0014] As it is known, a filter for the microwave band consists of a dielectric substrate 26, a ground conductor plane 28 on the back side of the substrate 26 and a microstrip transmission line conductor formed on the front surface of the dielectric substrate, the transmission line conductor comprising an input IN and an output OUT transmission line conductors which are connected to an external circuit and a plurality of resonators. Each resonator comprises a $\lambda/2$-length microstrip conductor (where λ is the line wavelength correspondent to the fundamental resonance frequency, f_0). Typically, the $\lambda/2$-length microstrip conductors are of hairpin type or of an edge-coupled (linear) type.

[0015] Fig. 1 shows a $\lambda/2$ microstrip transmission line 10 and desired (first) resonance mode (bold line 14). Second and third resonance modes are also indicated by respective dotted lines 16, 18.

[0016] Fig. 2 shows a third order hairpin bandpass filter layout according to the state of the art with an input transmission line conductor IN and an output transmission line conductor OUT. In the filter of Fig. 2, three U shaped microstrip conductors 101, 102, 103 are arranged side-by-side. It should be noticed that the layout of Fig. 2 (wherein the resonators 101, 102, 103 alternate, i.e. neighboring resonators face opposite directions) is purely exemplificative. This means that the basic idea of the present invention equally applies to resonators arranged in a hairpin-comb configuration.

[0017] The basic idea of the present invention consists in rejecting the second resonant response by "forcing" a low voltage in the middle of the half wavelength resonator, where a voltage null 12 would occur under normal operating conditions.

[0018] Note that the third resonance spurious response will typically take place at frequencies that are so high that in many cases it can be neglected by the system.

[0019] In other words the basic idea consists in creating a low impedance path between the half-wave resonator centre and the ground in order to attenuate the second harmonic spourious mode without influencing the main mode.

[0020] The low impedance path can be created by connecting a resistor (R1, R2, R3) in the middle of each half wavelength resonators 101, 102, 103, see for instance Figures 3 and 6. Fig. 6 shows a third order edge-coupled filter layout with second resonance suppressing resistors according to the present invention.

[0021] A low RF voltage can be easily guaranteed by placing low impedance, wide-band components (like for instance 100 Ω SMD resistors in 0603 size) between the ground plane and the center of the half-wave resonating lines of the filter. This extra component will not seriously perturb the normal operation of the filter (because it is positioned in a voltage node), but on the other hand it will strongly attenuate the second resonance mode of the transmission line, when the center point would otherwise be subject to voltage peaks instead.

[0022] In case of a hairpin structure, the resistors can be mounted on the same side as the filter transmission lines (the grounding can take place by means of appropriate via holes). In case of an edge-coupled structure, the via holes can be placed in the middle of the half-wave lines, and the resistors mounted on the ground plane side (see Fig. 8).

[0023] The present invention has been computer simulated and the simulation results are shown in Fig. 4 (for an hairpin filter) and in Fig. 7 (for an edge-coupled filter), respectively.

[0024] Fig. 4 shows a comparison between spurious responses of a 10 GHz hairpin filter according to the state of the art (dotted line 20) and according to the present invention (solid line 22). The graph shows that below 13000 MHz the spurious responses are the same but, starting from a frequency around 13000 MHz, the spurious responses become significantly lower than the prior art.

[0025] A similar situation can be depicted for a 10 GHz edge-coupled filter (see Fig. 7).

[0026] Fig. 8 shows a possible implementation of the present invention in case of microstrip edge-coupled structure. Conveniently, via holes 24 are made in the substrate 26 and the resistors R are arranged in the ground plane 26 which is opposite to the λ/2 resonating line.

[0027] In view of the above description, the advantages of the present invention are now certainly clear. The second harmonic response (i.e. the closest one to the desired passband) is strongly attenuated without the need for an extra lowpass filter, avoiding in this way the manufacturing and test of a second filter, and saving also some (often precious) space.

[0028] The third resonance mode (third harmonic response) is not affected (but as already mentioned, this will typically take place at frequencies that are so high, that in many cases it can be neglected by the system.

[0029] There have thus been shown and described a novel microwave filter and a novel method which fulfill all the objects and advantages sought therefor. Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering the specification and the accompanying drawings which disclose preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

Claims

1. Half-wave resonator providing reduced second armonic spurious mode, the resonator comprising a λ/2-length microstrip conductor, where A is the line wavelength correspondent to the fundamental resonance frequency, **characterized in that** it further comprises means for forcing a low voltage in the middle of the λ/2-length microstrip conductor.

2. Half-wave resonator according to claim 1, **characterized in that** said means for forcing a low voltage in the middle of the λ/2-length microstrip conductor comprise a low impedance, wide-band resistor.

3. Microwave band filter comprising:

   a dielectric substrate;
   a ground conductor plane on a back side of the substrate; and
   a transmission line conductor formed on the front surface of the dielectric substrate, the transmission line conductor comprising:

      an input and an output transmission line conductors which are connected to an external circuit; and
      at least one resonator comprising a λ/

2-length microstrip conductor, where λ is the line wavelength correspondent to the fundamental resonance frequency,

characterized in that it further comprises means for forcing a low voltage in the middle of the λ/2-length microstrip conductor.

4. Microwave band filter according to claim 3, **characterized in that** said means for forcing a low voltage in the middle of the λ/2-length microstrip conductor comprise a low impedance, wide-band resistor.

5. Microwave band filter according to claim 3 or 4, **characterized in that** said at least one resonator comprises a corresponding at least one λ/2-length microstrip conductor of an hairpin type

6. Microwave band filter according to claim 3 or 4, **characterized in that** said at least one resonator comprises a corresponding at least one λ/2-length microstrip conductor of an edge-coupled type.

7. Microwave band filter according to claim 6, **characterized in that** it further comprises at least a corresponding via hole for connecting said means for forcing a low voltage with the λ/2-length microstrip conductor.

8. Method for providing reduced second armonic spurious mode in a half-wave resonator, the resonator comprising a λ/2-length microstrip conductor, where λ is the line wavelength correspondent to the fundamental resonance frequency, **characterized in that** it comprises the step of forcing a low voltage in the middle of the λ/2-length microstrip conductor.

9. Method according to claim 8, **characterized in that** the step of forcing a low voltage in the middle of the λ/2-length microstrip conductor comprises the step of connecting a low impedance, wide-band resistor to the λ/2-length microstrip conductor at the middle area thereof.

10. Method for microwave band filtering signals, the method comprising the steps of:

providing a dielectric substrate;
providing a ground conductor plane on a back side of the substrate; and
providing a transmission line conductor formed on the front surface of the dielectric substrate, the transmission line conductor comprising:

an input and an output transmission line conductors which are connected to an external circuit; and
at least one resonator comprising a λ/2-length microstrip conductor, where λ is the line wavelength correspondent to the fundamental resonance frequency,

characterized by the step of forcing a low voltage in the middle of the λ/2-length microstrip conductor.

11. Method according to claim 10, **characterized in that** the step of forcing a low voltage in the middle of the λ/2-length microstrip conductor comprises the step of connecting a low impedance, wide-band resistor to the λ/2-length microstrip conductor at the middle area thereof.

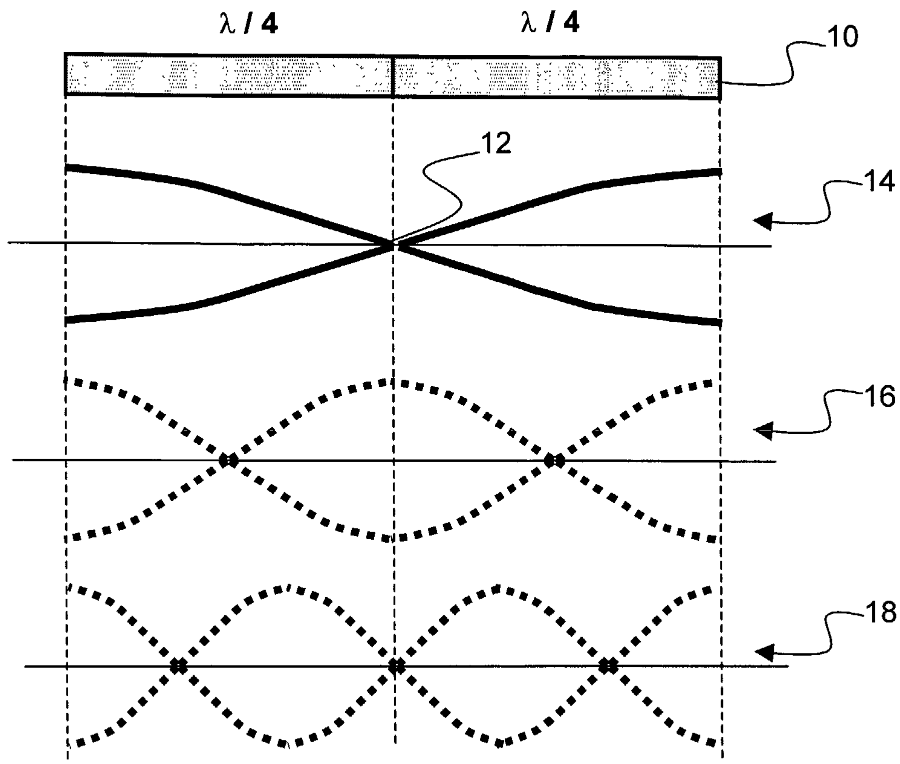


Fig. 1

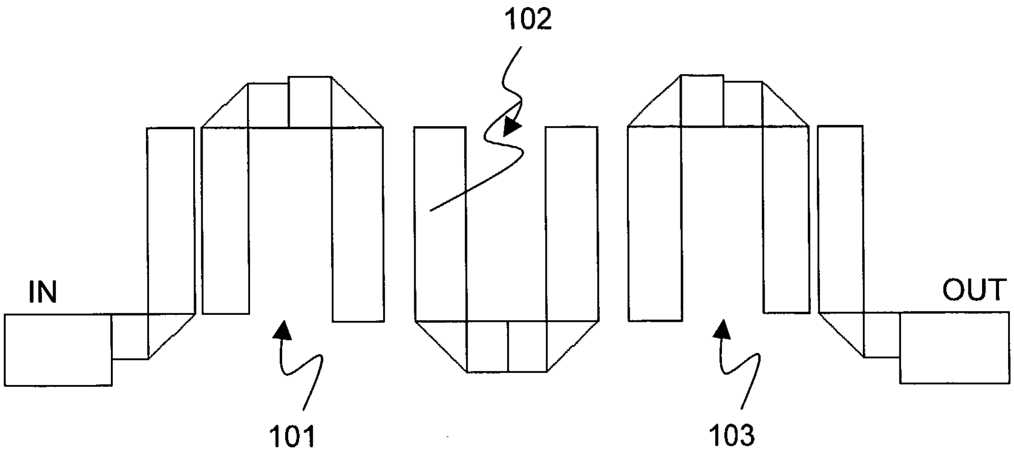


Fig. 2
(Prior Art)

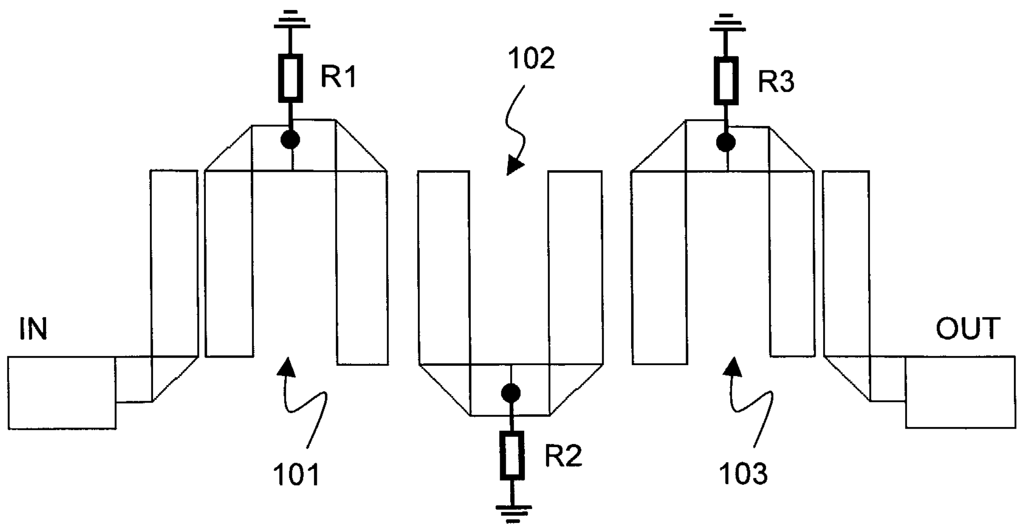
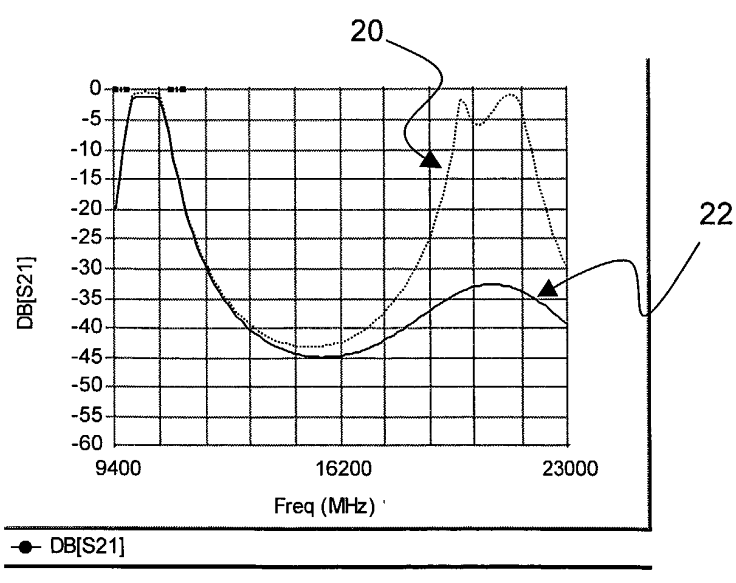

R1
102
R3
IN
OUT
101
R2
103

Fig. 3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-30
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-55
-60
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23000
Freq (MHz)
DB[S21]

Fig. 4

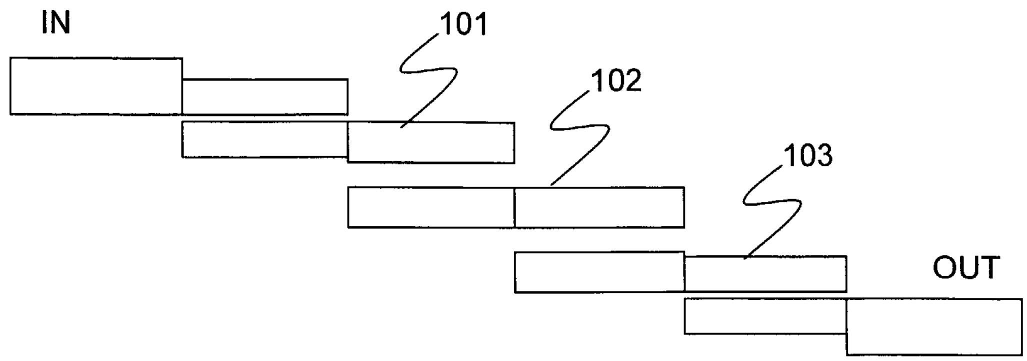


Fig. 5
(Prior Art)

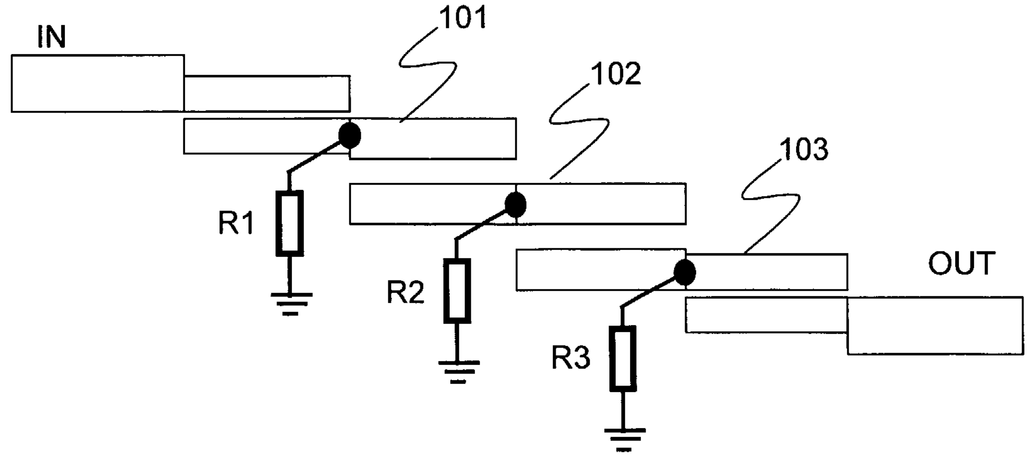
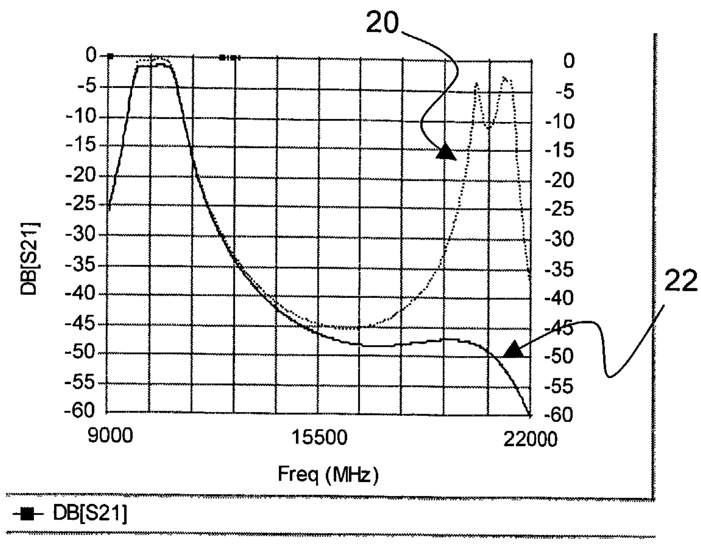


Fig. 6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Freq (MHz)
DB[S21]

Fig. 7

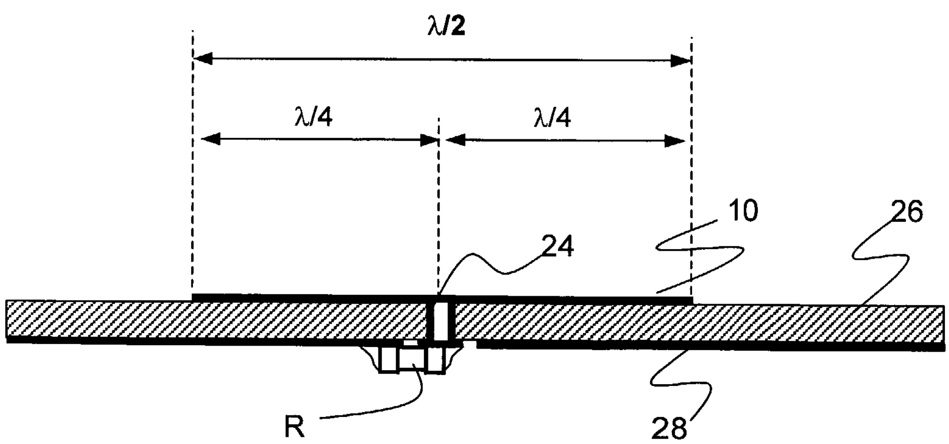
λ/2
λ/4
λ/4
10
26
24
R
28

Fig. 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 40 2437

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X Y	US 5 066 933 A (KOMEDA YASUHIKO) 19 November 1991 (1991-11-19) * the whole document * ---	1,3,5-8, 10 2,4,9,11	H01P1/203 H01P1/212 H01P7/08
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X	PATENT ABSTRACTS OF JAPAN vol. 015, no. 423 (E-1127), 28 October 1991 (1991-10-28) & JP 03 178201 A (SHARP CORP), 2 August 1991 (1991-08-02) * abstract * ---	1,3,6,8, 10	
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 285 (E-642), 4 August 1988 (1988-08-04) & JP 63 060604 A (SHARP CORP), 16 March 1988 (1988-03-16) * abstract * -----	1,3,8,10	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01P

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23 January 2002	Den Otter, A

CATEGORY OF CITED DOCUMENTS

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