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(54) Band-pass filter

(57) A band-pass filter (500) comprises a first resonator (501), a second resonator (502) and a third resonator (503). The second resonator (502) is magnetically coupled to the first resonator (501). The third resonator (503) is magnetically coupled to the second resonator (502) and is electrically coupled to the first resonator (501). In addition, the first resonator (501) is a quarter wavelength resonator, the second resonator (502) is a half wavelength resonator, and the third resonator (503) is a quarter wavelength resonator.

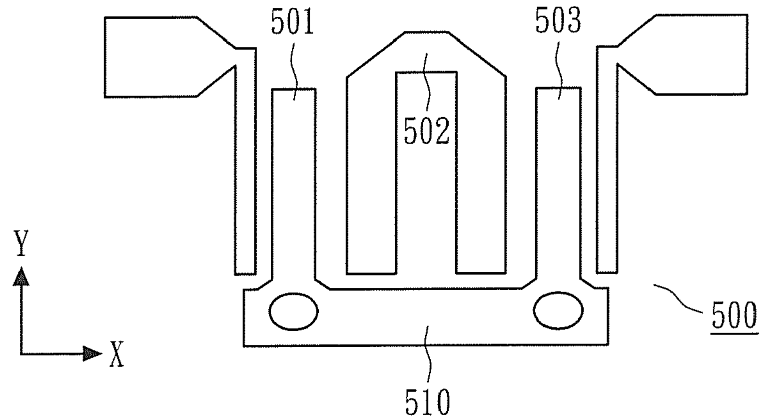

FIG. 5

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to filter design, and more particularly, to band-pass filter design.

DESCRIPTION OF THE RELATED ART

[0002] In typical receiver architecture, as shown in FIG. 1, when a receiver 100 receives a radio frequency (RF) signal with frequency f_R, the received RF signal is amplified by an RF antenna 101. Next, a mixer 102 and a local oscillator (LO) 103 are utilized to shift the frequency of the received RF signal to an intermediate frequency f_I for the subsequent signal processing. The LO 103 is configured to provide an LO signal with an adjustable frequency f_O. The mixer 102 is configured to perform a multiplying operation for the received RF signal and the LO signal to produce new signals of beat frequencies of $f_R + f_O$ and $f_R - f_O$. Ordinarily, the signal of frequency $f_R - f_O$ is the desired signal, wherein the frequency $f_R - f_O$ equals the intermediate frequency f_I, and the signal with frequency $f_R + f_O$ is the unwanted signal.

[0003] However, the RF antenna 101 may also receive image signals with image frequency f_W, wherein the image frequency f_W equals $f_O - f_I$. Accordingly, after the operation of the mixer 102, the image signals are also shifted to the intermediate frequency f_I since new signals of beat frequencies of $f_O + f_W$ and $f_O - f_W$ are also produced, wherein the frequency of $f_O - f_W$ equals the intermediate frequency f_I. As a result, the image signals will cause interferences with the received RF signal. Therefore, a band-pass filter 104 is often required to eliminate the image signals, as shown in FIG. 1.

[0004] One conventional band-pass filter structure is shown in FIG. 2. The band-pass filter 200 uses a hairpin structure. Another conventional band-pass filter structure is shown in FIG. 3. The band-pass filter 300 uses an inter-digital structure. FIG. 4 shows the frequency responses of the band-pass filters 200 and 300. As shown in FIG. 4, the hairpin band-pass filter 200 exhibits a steeper slope at the lower side of the pass band, i.e. the frequency band of the image signal, and a smaller gain at the pass band compared to the inter-digital band-pass filter 300. Accordingly, the hairpin band-pass filter 200 has a better image rejection capability at the lower side of the passband but a poor insertion loss compared to the inter-digital band-pass filter 300. On the other hand, the inter-digital band-pass filter 300 has a poor image rejection capability but a better insertion loss compared to the hairpin band-pass filter 200. In addition, as shown in FIGS. 2 and 3, the hairpin band-pass filter 200 requires more layout area.

[0005] Accordingly, neither the hairpin band-pass filter 200 shown in FIG. 2 nor the inter-digital band-pass filter 300 shown in FIG. 3 meets the requirements of modem band-pass filter design.

SUMMARY OF THE INVENTION

[0006] The band-pass filter according to one embodiment of the present invention comprises a first resonator, a second resonator and a third resonator. The second resonator is magnetically coupled to the first resonator. The third resonator is magnetically coupled to the second resonator and is electrically coupled to the first resonator. In addition, the first resonator is a quarter wavelength resonator, the second resonator is a half wavelength resonator, and the third resonator is a quarter wavelength resonator.

[0007] The band-pass filter according to another embodiment of the present invention comprises a plurality of half wavelength resonators and a plurality of quarter wavelength resonators. The plurality of half wavelength resonators and the plurality of quarter wavelength resonators are arranged along a first direction in an interleaved manner, and each of the two ends of the band-pass filter is arranged with a quarter wavelength resonator.

[0008] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter, and form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes as those of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The objectives and advantages of the present invention will become apparent upon reading the following description and upon referring to the accompanying drawings of which:

FIG. 1 shows a partial block diagram of typical receiver architecture;

FIG. 2 shows a conventional band-pass filter structure;

FIG. 3 shows another conventional band-pass filter structure;

FIG. 4 shows the frequency responses of two conventional band-pass filters;

FIG. 5 shows a band-pass filter structure according to an embodiment of the present invention;

FIG. 6 shows a coupling diagram of a band-pass filter according to an embodiment of the present invention;

FIG. 7 shows the frequency responses of two conventional band-pass filters and a band-pass filter according to an embodiment of the present invention;

FIG. 8 shows a band-pass filter structure according to another embodiment of the present invention; and

FIG. 9 shows a band-pass filter structure according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0010] FIG. 5 shows a band-pass filter structure according to an embodiment of the present invention. As shown in FIG. 5, the band-pass filter 500 comprises a first resonator 501, a second resonator 502 and a third resonator 503. The first resonator 501, the second resonator 502 and the third resonator 503 are arranged along the X-direction with the second resonator 502 sandwiched between the first resonator 501 and the third resonator 503. The first resonator 501 and the third resonator 503 are both quarter wavelength resonators. That is, the lengths of the first resonator 501 and the third resonator 503 are a quarter of the wavelength of the electromagnetic wave received by the band-pass filter 500. In addition, both the first resonator 501 and the third resonator 503 are in a long strip shape extending along the Y-direction. Further, both the first resonator 501 and the third resonator 503 have one end connected to a ground line 510. The second resonator 502 is a half wavelength resonator. That is, the length of the second resonator 502 is half of the wavelength of the electromagnetic wave received by the band-pass filter 500. In addition, the second resonator 502 is in a U shape with the opening facing the ground line 510.

[0011] FIG. 6 shows a coupling diagram of the band-pass filter 500 shown in FIG. 5. As shown in FIG. 6, the magnetic coupling between the first resonator 501 and the second resonator 502 is strong. Accordingly, the coupling between the first resonator 501 and the second resonator 502 is represented by an inductance L1. Likewise, the magnetic coupling between the second resonator 502 and the third resonator 503 is also strong. Therefore, the coupling between the second resonator 502 and the third resonator 503 is represented by an inductance L2. However, the magnetic coupling between the first resonator 501 and the third resonator 503 is weak and the electric coupling dominates the coupling between both resonators. Accordingly, the first resonator 501 and the third resonator 503 is represented by a conductance C1.

[0012] It can be seen that when the band-pass filter 500 is operated below resonance, the phase of the first path, which is from the first resonator 501 to the third resonator 503 passing through the second resonator 502, is -90 degrees. On the other hand, the phase of the second path, which is from the first resonator 501 directly to the third resonator 503, is 90 degrees. That is, when the band-pass filter 500 is operated below resonance, the first path and the second path are out of phase, which accordingly introduces a transmission zero at the lower side of the pass band of the band-pass filter 500.

[0013] FIG. 7 shows the frequency responses of the band-pass filters 200, 300 and 500. As shown in FIG. 7, the frequency response of the band-pass filter 500 has a transmission zero at the lower side of the pass band, which produces a steep slope at the lower side of the pass band. Accordingly, the band-pass filter 500 has a great image rejection capability. In addition, as shown in FIG. 7, the band-pass filter 500 also exhibits a small insertion loss.

[0014] FIG. 5 shows a three-order band-pass filter 500. However, the present invention is not limited to a three-order band-pass filter, and should cover any other higher-order band-pass filters with the same structure concept. FIG. 8 shows a band-pass filter structure according to another embodiment of the present invention. As shown in FIG. 8, the band-pass filter 800 comprises three quarter wavelength resonators 801, 802 and 803 and two half wavelength resonators 804 and 805. The three quarter wavelength resonators 801, 802 and 803 and the two half wavelength resonators 804 and 805 are arranged along the X-direction in an interleaved manner with each of the two ends of the band-pass filter 800 arranged with a quarter wavelength resonator 801 and 803 respectively. Accordingly, the band-pass filter 800 is a five-order band-pass filter.

[0015] FIG. 9 shows a band-pass filter structure according to yet another embodiment of the present invention. As shown in FIG. 9, the band-pass filter 900 comprises four quarter wavelength resonators 901, 902, 903 and 904 and three half wavelength resonators 905, 906 and 907. The four quarter wavelength resonators 901, 902, 903 and 904 and the three half wavelength resonators 905, 906 and 907 are arranged along the X-direction in an interleaved manner with each of the two ends of the band-pass filter 900 arranged with a quarter wavelength resonator 901 and 904 respectively. Accordingly, the band-pass filter 900 is a seven-order band-pass filter.

[0016] In conclusion, the present invention provides band-pass filters exhibiting great image rejection capability and small insertion loss. In addition, the layout areas of the band-pass filters provided by the present invention can meet the requirement of the modem filter design. Therefore, the band-pass filters provided by the present invention are suitable for the low noise block specified in North American standard, i.e. the frequency band between 12.2GHz and 12.7GHz, and the low noise block specified in European standard, i.e. the frequency band between 10.7GHz and 12.75GHz.

[0017] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. For example, many of the processes discussed above can be implemented in different methodologies and replaced by other processes, or a combination thereof.

[0018] Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

Claims

1. A band-pass filter (500), comprising:

a first resonator (501);
a second resonator (502) magnetically coupled to the first resonator; and
a third resonator (503) magnetically coupled to the second resonator and electrically coupled to the first resonator;

wherein the first resonator is a quarter wavelength resonator, the second resonator is a half wavelength resonator, and the third resonator is a quarter wavelength resonator.

2. The band-pass filter (500) of claim 1, wherein both the first resonator (501) and the third resonator (503) are in a long strip shape extending along a first direction.

3. The band-pass filter (500) of claim 2, wherein the first resonator, the second resonator (502) and the third resonator (503) are aligned along a second direction perpendicular to the first direction with the second resonator sandwiched between the first resonator and the third resonator.

4. The band-pass filter (500) of claim 3, wherein both the first resonator (501) and the third resonator (503) have a lower end connected to a ground side.

5. The band-pass filter (500) of claim 4, wherein the second resonator (502) is in a U shape with an opening facing the ground side.

6. The band-pass filter (500) of one of the preceding claims, wherein the first resonator (501) and the third resonator (503) are grounded.

7. The band-pass filter (500) of one of the preceding claims, wherein the second resonator (502) is in a U shape.

8. The band-pass filter (500) of one of the preceding claims, the frequency response of which has a transmission zero at a lower side of the pass band.

9. The band-pass filter (500) of one of the preceding claims, which is applied to a radio frequency system with a frequency band between 10.7GHz and 12.75GHz or to a radio frequency system with a frequency band between 12.2GHz and 12.7GHz.

10. A band-pass filter (800), comprising:

a plurality of half wavelength resonators (804, 805); and
a plurality of quarter wavelength resonators (801, 802, 803);

wherein the plurality of half wavelength resonators and the plurality of quarter wavelength resonators are arranged along a first direction in an interleaved manner with each of two ends of the band-pass filter arranged with a quarter wavelength resonator.

11. The band-pass filter of claim 11, wherein each of the quarter wavelength resonators (801, 802, 803) is in a long strip shape extending along a second direction perpendicular to the first direction.

12. The band-pass filter of claim 11 or 12, wherein each of the quarter wavelength resonators (801, 802, 803) has a lower end connected to a ground side.

13. The band-pass filter of claim 13, wherein each of the half resonators (804, 805) is in a U shape with an opening facing the ground side.

14. The band-pass filter of one of the claims 11 to 14, wherein each of the half resonators (804, 805) is in a U shape.

15. The band-pass filter of one of the claims 11 to 15, the frequency response of which has a transmission zero at a lower side of the pass band.

16. The band-pass filter of one of the claims 11 to 16, wherein each of the plurality of quarter wavelength resonators (801, 802, 803) is magnetically coupled to at least one of the plurality of half wavelength resonators (804, 805).

17. The band-pass filter of one of the claims 11 to 17, wherein each of the plurality of quarter wavelength resonators (801, 802, 803) is electrically coupled to at least one of the other quarter wavelength resonators.

18. The band-pass filter of one of the claims 11 to 18, which is applied to a radio frequency system with a frequency band between 10.7GHz and 12.75GHz or to a radio frequency system with a frequency band between 12.2GHz and 12.7GHz.

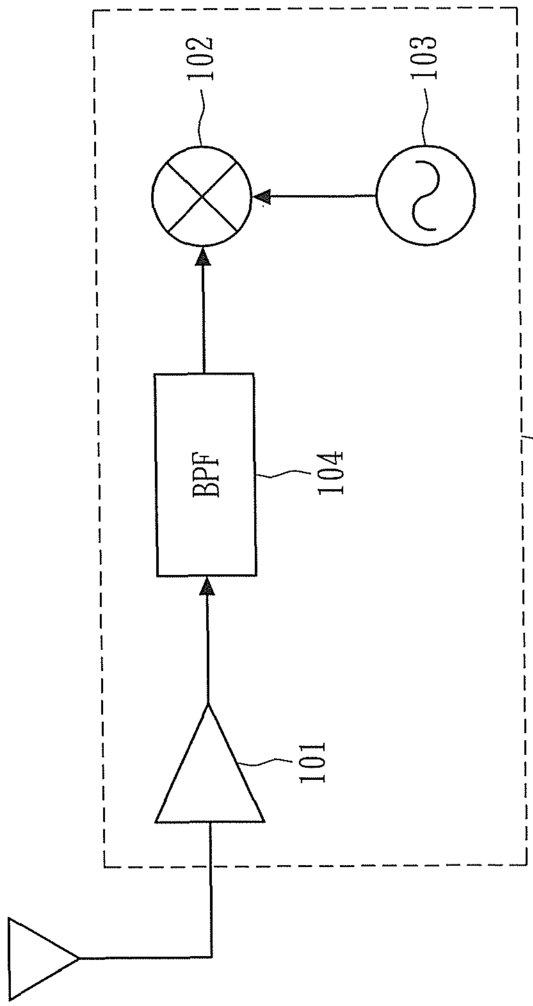


FIG. 1 (Prior Art)

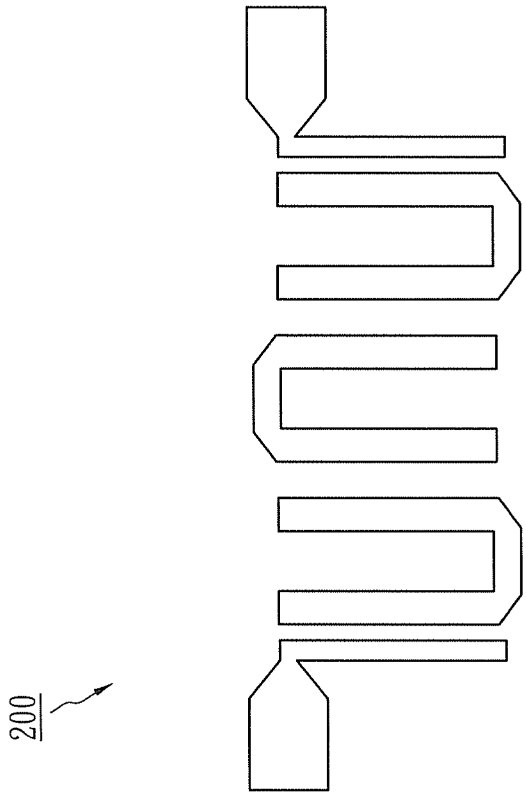


FIG. 2 (Prior Art)

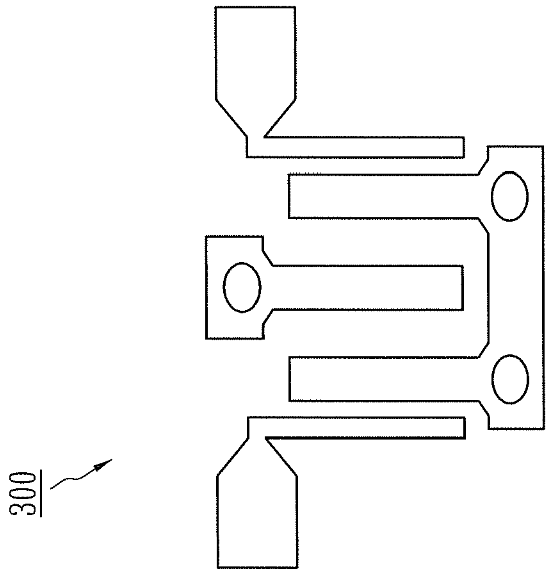


FIG. 3 (Prior Art)

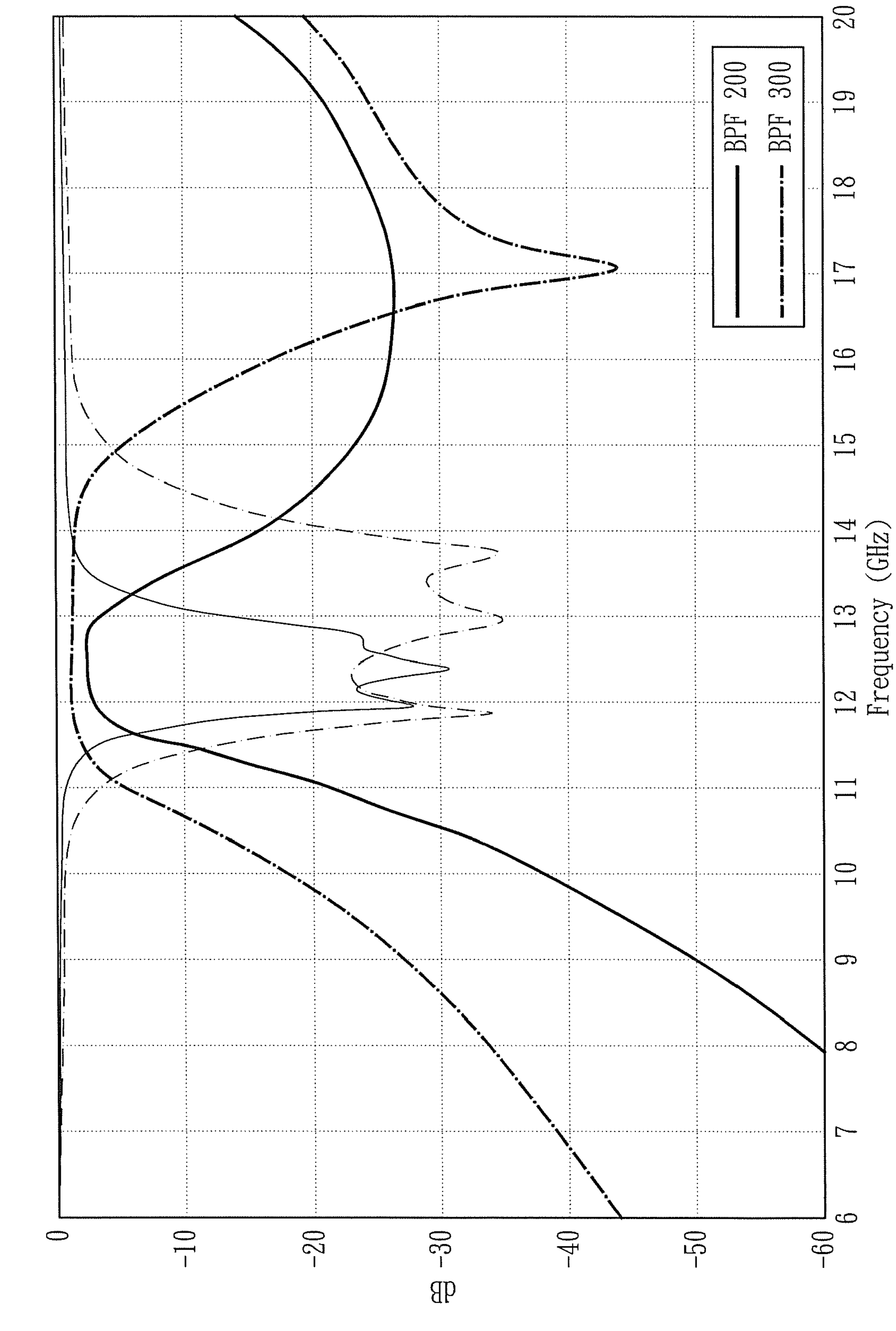


FIG. 4 (Prior Art)

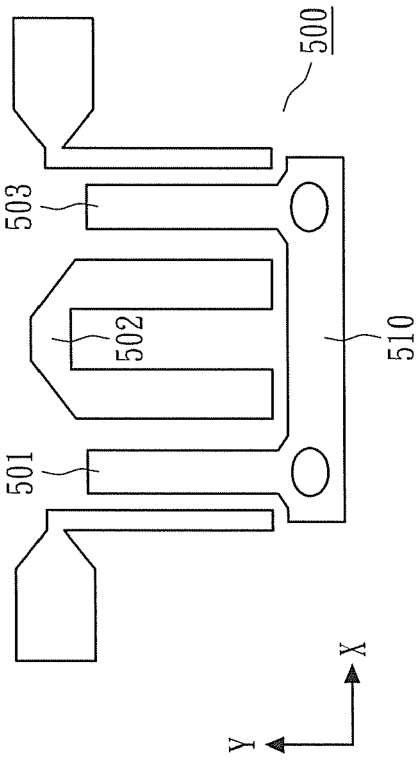


FIG. 5

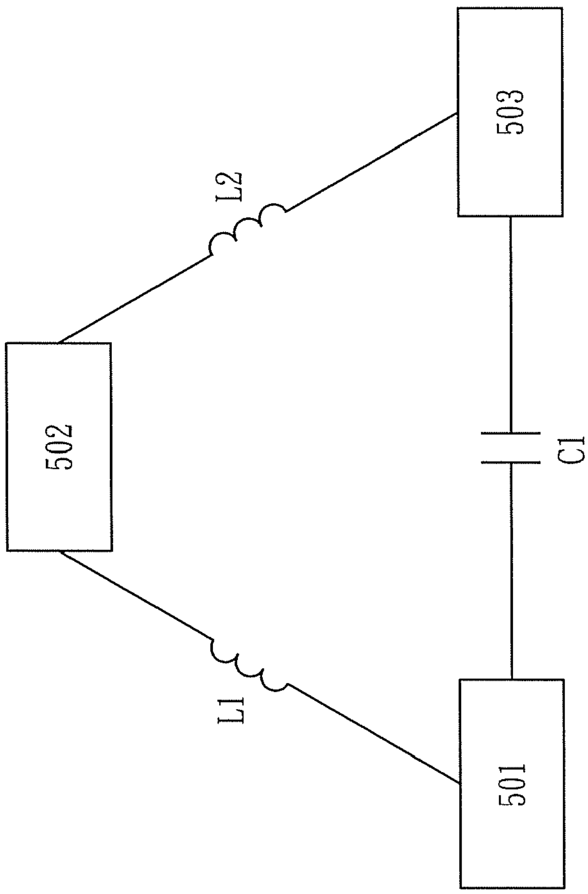
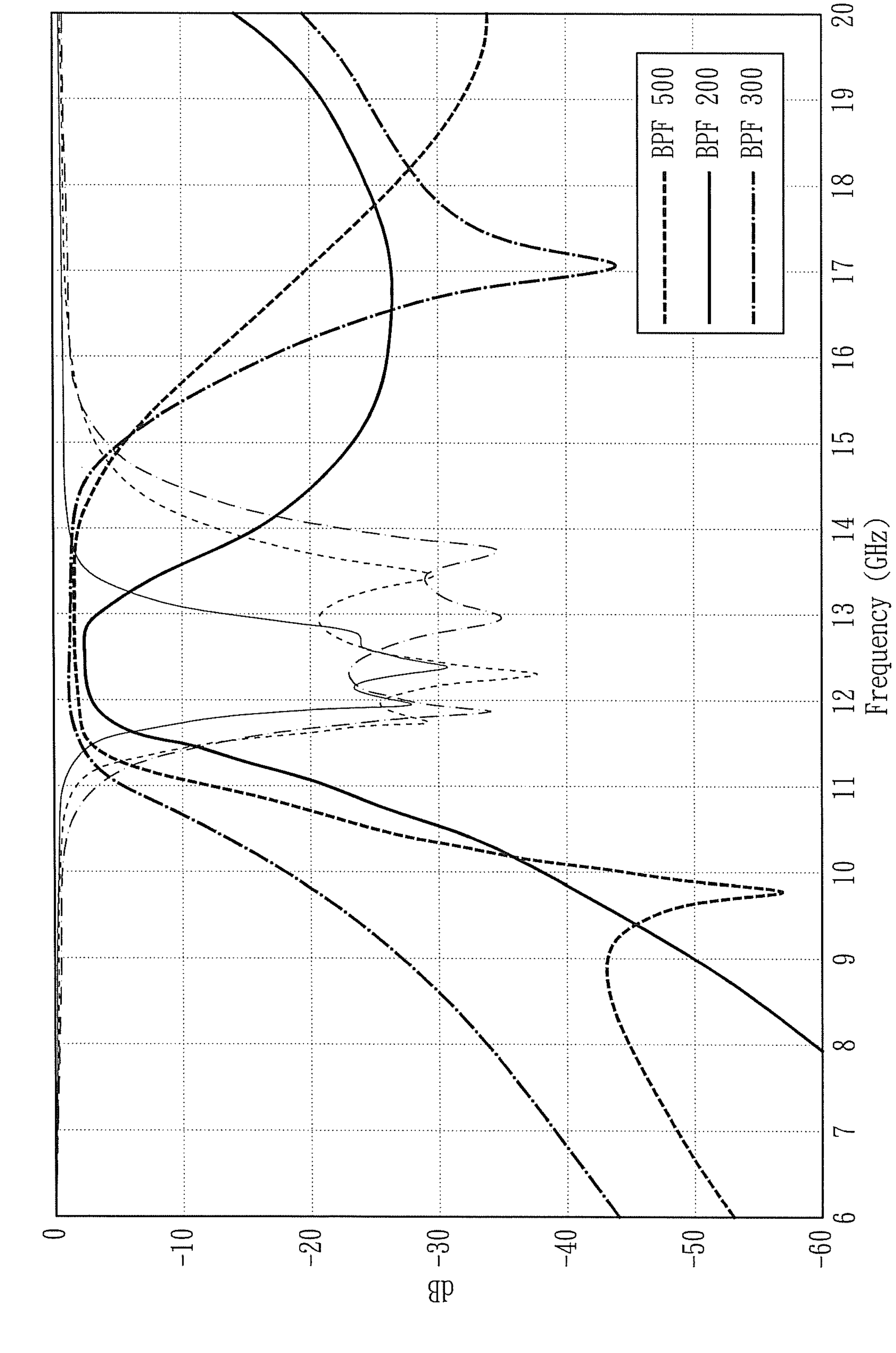


FIG. 6


BPF 500
BPF 200
BPF 300
Frequency (GHz)
dB
6
7
8
9
10
11
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-60

FIG. 7

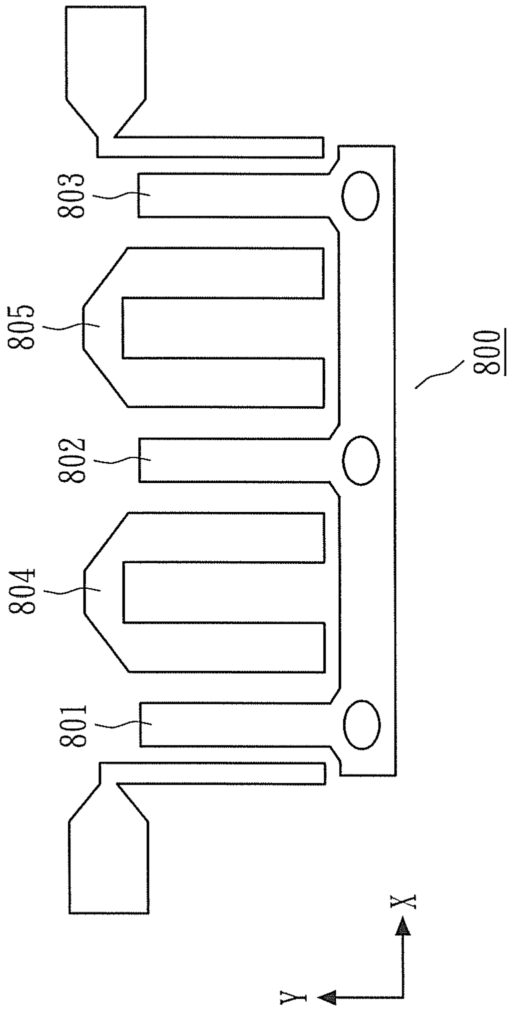

FIG. 8

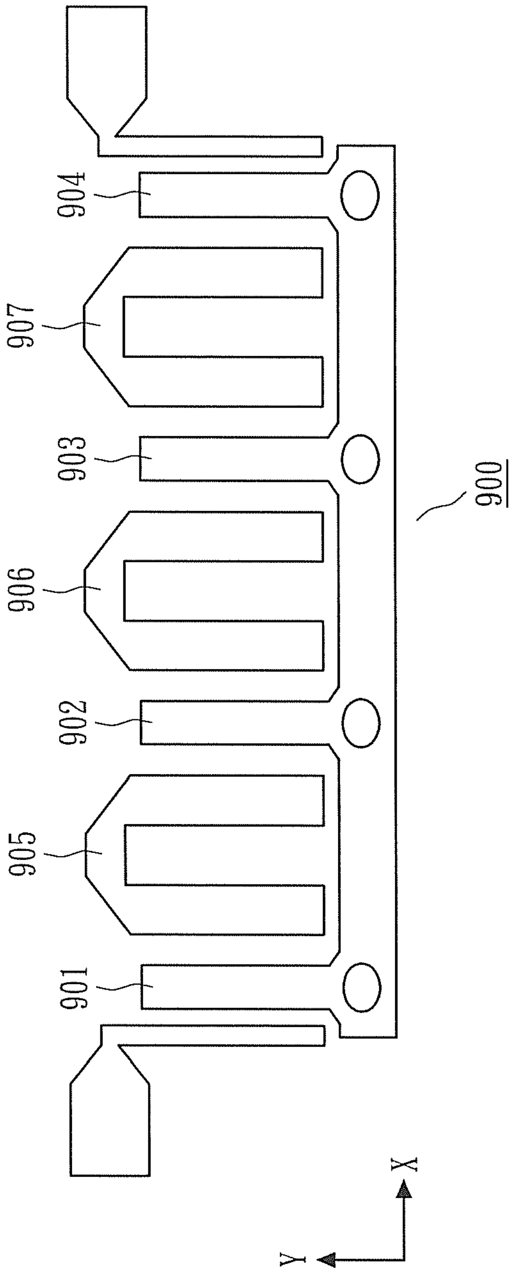

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 11 16 3239

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 Y	WO 2010/137398 A1 (MURATA MANUFACTURING CO [JP]; TAKEI YASUNORI [JP]; TSUJIGUCHI TATSUYA) 2 December 2010 (2010-12-02) * the whole document * -----	1-9 10-18	INV. H01P1/203
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A	CHENG-CHUNG CHEN ET AL: "A novel coupling structure suitable for cross-coupled filters with folded quarter-wave resonators", IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 13, no. 12, 1 December 2003 (2003-12-01), pages 517-519, XP011106053, ISSN: 1531-1309, DOI: DOI:10.1109/LMWC.2003.819957 * the whole document * -----	1	TECHNICAL FIELDS SEARCHED (IPC) H01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 June 2011	Ribbe, Jonas

CATEGORY OF CITED DOCUMENTS

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