A printed filtering antenna is provided. This filtering antenna comprises an antenna part and a coupled line resonator. The antenna part is directly connected to a coupled line resonator and occupies an antenna area. The coupled line resonator provides a filtering mechanism together with the antenna part. The coupled line resonator comprises a short-circuited stub and an open-circuited stub. The short-circuited stub comprises an open-circuited end and a short-circuited end connected to ground. The open-circuited stub is parallel to the short-circuited stub. The open-circuited stub comprises a first end and a second end. The first end is connected to the feed point and is corresponding to the open-circuited end of the short-circuited stub such that the open-circuited stub is coupled to the short-circuited stub.
FIG. 3

FIG. 4
PREN Printed Filtering Antenna

RELATED APPLICATIONS

This application claims priority to Taiwan Application Serial Number 100130932, filed Aug. 29, 2011, which is herein incorporated by reference.

BACKGROUND

1. Technical Field
The present disclosure relates to an antenna device. More particularly, the present disclosure relates to a printed filtering antenna.

2. Description of Related Art
There are some remarkable aspects to the rapid growth in wireless communications, as typified by the rapid growth in mobile telephony. In a wireless communication system, the antenna plays an important role. A well-designed antenna can deliver and receive a wireless signal within the requested frequency band with good quality, regardless of the location or the orientation of the antenna. In recent years, there has been a trend toward small and simple designs of antennas. Hence, the printed antenna has been popular for various applications due to their low cost, easy fabrication, low profile, and compatibility with integrated circuits.

Since it is necessary to process a signal within a specific range of a frequency band, the filter is important to the design of the overall antenna structure. Recently, some technologies propose a filtering antenna in which an antenna is used to replace the last order of the resonator and the resistive load of the filter. However, when the filter and the antenna are integrated together, the overall area of the circuit will increase as well, which runs counter to the design trend described above.

Accordingly, what is needed is a printed filtering antenna to realize a good filtering mechanism while maintaining a smaller size. The present disclosure addresses such a need.

SUMMARY

An aspect of the present disclosure is to provide a printed filtering antenna. The printed filtering antenna comprises an antenna port and a coupled line resonator connected to the antenna port to provide a filtering mechanism together with the antenna part. The coupled line resonator comprises a short-circuited stub and an open-circuited stub. The short-circuited stub comprises an open-circuited end and a short-circuited end connected to ground. The open-circuited stub is parallel to the short-circuited stub. A gap is formed between the open-circuited stub and the short-circuited stub. The open-circuited stub comprises a first end and a second end in which the first end is connected to the antenna part and is corresponding to the open-circuited end of the short-circuited stub such that the open-circuited stub is coupled to the short-circuited stub.

It is to be understood that both the foregoing general description and the following detailed description are by examples, and are intended to provide further explanation of the disclosure as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure can be more fully understood by reading the following detailed description of the embodiments, with reference made to the accompanying drawings as follows:

FIG. 1A and FIG. 1B are geometrical diagrams of a printed filtering antenna in two embodiments of the present disclosure;

FIG. 2A to FIG. 2C are diagrams of equivalent circuits of an open-circuited stub and a short-circuited stub in an embodiment of the present disclosure;

FIG. 3 is a diagram of simulation results of a geometrical structure and an equivalent circuit of a coupled line resonator in an embodiment of the present disclosure;

FIG. 4 is a diagram similar to FIG. 3, but illustrating simulation results when the length of the open-circuited stub is varied;

FIG. 5A to FIG. 5C are diagrams of equivalent circuits of the printed filtering antenna in an embodiment of the present disclosure;

FIG. 6 is a top view of the printed filtering antenna in an embodiment of the present disclosure;

FIG. 7 is a partially enlarged view of the printed filtering antenna in FIG. 6;

FIG. 8 is a cross-sectional view of the coupled line resonator in FIG. 7 taken along line P-P';

FIG. 9 and FIG. 10 are two top views of the printed filtering antenna of two embodiments of the present disclosure;

FIG. 11A is a diagram of the frequency response of the return loss of the printed filtering antenna of the present disclosure and of a conventional single Γ-shaped antenna;

FIG. 11B is a diagram of the frequency response of the total radiated power of the printed filtering antenna of the present disclosure and of the conventional single Γ-shaped antenna.

FIG. 12A and FIG. 12B are diagrams of the response of the antenna gain with respect to frequency along direction ±z and direction ±x of the printed filtering antenna of the present disclosure and the conventional single Γ-shaped antenna;

FIG. 13A to FIG. 13C are diagrams of measuring results of antenna radiation patterns on the x-z, y-z, and x-y planes respectively; and

FIG. 14 is a top view of an Nth-order printed filtering antenna in an embodiment of the present disclosure.

DETAILED DESCRIPTION

Reference will now be made in detail to the present embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

FIG. 1A is a geometrical diagram of a printed filtering antenna 1 in an embodiment of the present disclosure. The printed filtering antenna 1 comprises an antenna port 10 and a coupled line resonator 12.

In different embodiments, the antenna port 10 can be a monopole antenna with a Γ-shaped, an F-shaped, an inverted-F antenna or another type of antenna. In FIG. 1A, point A is a feed point of the antenna port 10. The coupled line resonator 12 is connected to the antenna port 10 to provide a filtering mechanism together with the antenna port 10. As depicted in FIG. 1A, the coupled line resonator 12 comprises an open-circuited stub 20 and a short-circuited stub 22. In the present embodiment, the printed filtering antenna 1 comprises only one coupled line resonator 12. Consequently, the order of the coupled line resonator 12 is one and the printed filtering antenna 1 is a second-order filtering antenna.

The open-circuited stub 20 of the coupled line resonator 12 comprises a first end and a second end. The first end of the open-circuited stub 20 is connected to point A, i.e., the feed point of the antenna port 10. The second end is depicted as point C in FIG. 1A. A gap 24 is formed between the open-
circuited stub 20 and the short-circuited stub 22. That is, the open-circuited stub 20 and the short-circuited stub 22 are parallel to each other and the gap 24 is formed therebetween. The short-circuited stub 22 comprises an open-circuited end and a short-circuited end. The open-circuited end corresponds to the first end of the open-circuited stub 20. The short-circuited end is at point B in FIG. 1A.

In the present embodiment, a first electric length of the open-circuited stub 20 and a second electric length of the short-circuited stub 22 are equal. In other words, each of the open-circuited stub 20 and the short-circuited stub 22 is a quarter-wavelength circuit. In other embodiments, the open-circuited stub 20 and the short-circuited stub 22 can be designed such that they have unequal lengths as shown in FIG. 1B.

The gap 24 between the open-circuited stub 20 and the short-circuited stub 22 allows the open-circuited stub 20 and the short-circuited stub 22 to be electromagnetically coupled to each other. FIG. 2A to FIG. 2C are diagrams of equivalent circuits of the open-circuited stub 20 and the short-circuited stub 22 in an embodiment of the present disclosure. Taking the open-circuited stub 20 and the short-circuited stub 22 depicted in FIG. 1A that have the same electric length as an example, the equivalent circuit of the open-circuited stub 20 and the short-circuited stub 22 comprises a series-connected inductor-capacitor (LC) resonator La/Ca and a parallel-connected inductor-capacitor (LC) resonator Lb/Cb. The gap 24 between the open-circuited stub 20 and the short-circuited stub 22 acts as a J-inverter. Though the open-circuited stub 20 and the short-circuited stub 22 have the same length and the same width, the series-connected LC resonator La/Ca and the parallel-connected LC resonator Lb/Cb have different resonant frequencies due to the coupling effect between them.

The equivalent circuit in FIG. 2A can be further transformed into the equivalent circuit in FIG. 2B. The equivalent circuit shown in FIG. 2B comprises two groups of series-connected LC resonators La/Ca and Lb/Cb that are connected in parallel. The series-connected LC resonators La/Ca have a resonant frequency f1 and the series-connected LC resonators Lb/Cb have a resonant frequency f2. Consequently, the two groups of series-connected LC resonators La/Ca and Lb/Cb generate two symmetric transmission zeros at a band edge of the printed filtering antenna 1. The equivalent circuit in FIG. 2B can be further transformed into the equivalent circuit in FIG. 2C around the resonant frequency fr, in which the equivalent circuit in FIG. 2C comprises a group of parallel-connected LC resonator L1/C1.

FIG. 3 is a diagram of simulation results of a geometrical structure and an equivalent circuit of the coupled line resonator 12 in an embodiment of the present disclosure. The x-axis in FIG. 3 represents the frequency (GHz) and the y-axis represents the S-parameter (dB). In the present embodiment, the widths of both of the open-circuited stub 20 and the short-circuited stub 22 are 0.5 mm. The width of the gap 24 is 0.2 mm. The open-circuited stub 20 and the short-circuited stub 22 are formed on a substrate having a thickness of 0.508 mm, a dielectric constant of 3.38 and a loss tangent of 0.0027. The solid lines in FIG. 3 represent the simulation result of the coupled line resonator 12 depicted in FIG. 1A. The dashed lines in FIG. 3 represent the simulation result of the equivalent circuit depicted in FIG. 2B. The dotted lines in FIG. 3 represent the simulation result of the equivalent circuit depicted in FIG. 2C.

As shown in FIG. 3, the simulation results of the equivalent circuit depicted in FIG. 2B and the coupled line resonator 12 depicted in FIG. 1A are nearly identical. The simulation results of the equivalent circuit depicted in FIG. 2C and the coupled line resonator 12 depicted in FIG. 1A are also similar around the resonant frequency fr. The part labeled S11 in FIG. 3 indicate the curves of the reflection coefficient and the part labeled S12 in FIG. 3 indicate the curves of the refraction coefficient. The transmission pole generated at the resonant frequency fr is at about 2.5 GHz. The two symmetric transmission zeros at the band edge are generated approximately at 2.0 GHz and 3.0 GHz respectively.

When the open-circuited stub 20 and the short-circuited stub 22 are designed to have unequal lengths as depicted in FIG. 1B, two asymmetric transmission zeros are generated at the band edge. FIG. 4 is a diagram similar to FIG. 3, but illustrating simulation results when the electric length of the short-circuited stub 22 is fixed at 0–π/2 (at resonant frequency) and the length θ1 of the open-circuited stub 20 varies. As shown in FIG. 4, when θ1 gradually decreases, the resonant frequency (2.5 GHz) does not change but the location of the transmission zeros moves toward higher frequency. Hence, the length θ1 of the open-circuited stub 20 can be adjusted according to the demand of the position of the transmission zeros.

FIG. 5A to FIG. 5C are diagrams of equivalent circuits of the printed filtering antenna 1 comprising the antenna part 10 and the coupled line resonator 12 in an embodiment of the present disclosure. The coupled line resonator 12 in FIG. 5A is the same as the coupled line resonator 12 depicted in FIG. 2B and the coupled line resonator 12 in FIG. 5B is the same as the coupled line resonator 12 depicted in FIG. 2C. Hence, in addition to generating the frequency response of the second-order filtering antenna, the coupled line resonator 12 is able to generate two transmission zeros at the band edge. When the resonant frequency of the coupled line resonator 12 depicted is around fr, the printed filtering antenna 1 in FIG. 5A is transformed to the equivalent circuit depicted in FIG. 5B and is further transformed to the equivalent circuit depicted in FIG. 5C. The circuit depicted in FIG. 5C is an equivalent circuit of a typical second-order band-pass filter, where L2=La, C2=Ca, R0=Ra and C1=1/C1+Cg.

FIG. 6 is a top view of the printed filtering antenna 1 of an embodiment of the present disclosure. FIG. 7 is a partially enlarged view of the printed filtering antenna 1 in FIG. 6. In the present embodiment, the antenna part 10 of the printed filtering antenna 1 is a Γ-shaped monopole antenna having an antenna area 100. Point A in FIG. 7 is the feed point of the antenna part 10.

The coupled line resonator 12 is formed in the antenna area 100 and is connected to the antenna part 10 to provide a filtering mechanism together with the antenna part 10. FIG. 8 is a cross-sectional view of the coupled line resonator 12 in FIG. 7 taken along line P–P'. In the present embodiment, the to open-circuited stub 20 is a micro strip and the short-circuited stub 22 is a coplanar waveguide (CPW). In the present embodiment, the printed filtering antenna 1 further comprises a substrate 8 disposed between the open-circuited stub 20 and the short-circuited stub 22 to form the gap 24 depicted in FIG. 1A. The black region depicted in FIG. 6 is the layout formed above the substrate 8 and the gray region is the layout formed under the substrate 8. In order to depict the structure of the open-circuited stub 20 and the short-circuited stub 22 clearly, the substrate is not shown in FIG. 6 and FIG. 7. Accordingly, the open-circuited stub 20 and the short-circuited stub 22 are formed on the opposite side of the substrate 8. In the present embodiment, the short-circuited stub 22 is an extension of a ground surface 6 (depicted in FIG. 6) under the substrate 8.

Hence, the open-circuited stub 20 and the short-circuited stub 22 can accomplish the filtering mechanism and provide
a better selection of the band edge through the side coupling
5
effect between the open-circuited stub 20 and the short-circuited
6 stub 22. Further, the total area of the printed filtering
7 antenna 1 does not increase since the coupled line resonator
8 12 is disposed in the antenna area 100. The small size of the
9 printed filtering antenna 1 can be maintained.
10
11 FIG. 9 and FIG. 10 are two top views of the printed filtering
12 antenna 1 of two embodiments of the present disclosure. The
13 antenna part 10 in FIG. 9 is an F antenna, in which the coupled
14 line resonator 12 is disposed in the antenna area 100 occupied
15 by the antenna part 10. On the other hand, the open-circuited
16 stub 20 and the short-circuited stub 22 of the coupled line
17 resonator 12 in FIG. 10 are both micro strips formed on the
18 same plane, in which the two micro strips are separated by a
19 gap to form the structure depicted in FIG. 1A. In other
20 embodiments, the structure of slot line, coplanar stripline
21 (CPS), or the transmission line other than the micro strip and
22 the CPW can also be used to form the open-circuited stub 20
23 and the short-circuited stub 22 of the coupled line resonator
24 12.
25
26 FIG. 11A is a diagram of the frequency response of the
27 return loss of the printed filtering antenna 1 of the present
28 disclosure and of a conventional single Γ-shaped antenna.
29 FIG. 11B is a diagram of the frequency response of the total
30 radiated power of the printed filtering antenna 1 of the present
31 disclosure and of the conventional single Γ-shaped antenna.
32 The solid lines in FIG. 11A and FIG. 11B represent the
33 measuring results of the printed filtering antenna 1 of the
34 present disclosure. The dashed lines in FIG. 11A and FIG.
35 11B represent the simulation results of the printed filtering
36 antenna 1 of the present disclosure. The dotted lines in FIG.
37 11A and FIG. 11B represent the simulation results of the
38 conventional single Γ-shaped antenna. The simulation results
39 of the printed filtering antenna 1 show that two poles are
40 generated at 2.11 GHz and 3.31 GHz. Moreover, the
41 simulated radiating efficiency around the operation frequency
42 2.45 GHz is 82% and the simulated radiating efficiency
43 around the two transmission zeros is 0.7% and 1.1%,
44 respectively. The simulation results match the measuring
45 results of the printed filtering antenna. From FIG. 11A
46 and FIG. 11B, it is clear that when compared to the conventional
47 single Γ-shaped antenna having the same area, the printed
48 filtering antenna of the present disclosure provides a
49 smoother full-wave power response of the radiated power, a
50 better selection of the band edge and a better rejection of the
51 stop band.
52
53 FIG. 12A and FIG. 12B are diagrams of the response of the
54 antenna gain with respect to frequency along direction xZ and
direction of the printed filtering antenna 1 of the present
55 disclosure and the conventional single Γ-shaped antenna, in
56 which the actual direction of the directions x and y are
57 depicted in FIG. 6 and the actual direction of the direction z is
58 the direction pointing out of the paper. The solid lines in FIG.
59 12A and FIG. 12B represent the measuring results of the
60 printed filtering antenna 1 of the present disclosure. The
dashed lines in FIG. 12A and FIG. 12B represent the
61 simulation results of the printed filtering antenna 1 of the present
62 disclosure. The dotted lines in FIG. 12A and FIG. 12B
63 represent the simulation results of the conventional single
64 Γ-shaped antenna. From FIG. 12A and FIG. 12B, it is clear
65 that when compared to the conventional single Γ-shaped
66 antenna having the same area, the printed filtering antenna of
67 the present disclosure provides a smoother response of the
68 full-wave power radiation, a better selection of the band edge
69 and a better rejection of the stop band.
70
71 FIG. 13A to FIG. 13C are diagrams of measuring results of
72 the antenna radiation pattern on the x-Z plane, y-Z plane and
73 x-y plane respectively when the printed filtering antenna 1 is
74 at a central frequency of 2.45 GHz. On the x-Z plane, the
75 antenna radiation pattern is omni-directional. The maximum
76 of the antenna gain is 1.2 dBi. From FIG. 13A to FIG. 13C, it
77 is clear that when compared to the conventional single
78 Γ-shaped antenna having the same area, the printed filtering
79 antenna 1 of the present disclosure maintains better consistency.
80
81 In the previous embodiments, the order of the coupled line
82 resonator is one and the printed filtering antenna is a second
83 order filtering antenna. However, the printed filtering antenna
84 can be expanded to an Nth-order. FIG. 14 is a top view of a
85 printed filtering antenna 1' in an embodiment of the present
86 disclosure. In the present embodiment, the order of the
87 coupled line resonator is N-1 such that the printed filtering
88 antenna 1' becomes an Nth order filtering antenna. Each order
89 of the coupled line resonator is coupled to each other and only
90 one order of the coupled line resonator (the N-1th order in the
91 present embodiment) is connected to the antenna part 10
92 directly.
93
94 It will be apparent to those skilled in the art that various
95 modifications and variations can be made to the structure of
96 the present disclosure without departing from the scope or
97 spirit of the disclosure. In view of the foregoing, it is intended
98 that the present disclosure cover modifications and variations
99 of this disclosure provided they fall within the scope of the
100 following claims.
101
102 What is claimed is:
103
104 1. A printed filtering antenna, comprising:
105 an antenna part; and
106 a coupled line resonator connected to the antenna part to
107 provide a filtering mechanism together with the antenna
108 part, wherein the coupled line resonator comprises:
109 a short-circuited stub comprising an open-circuited end
110 and a short-circuited end connected to ground; and
111 an open-circuited stub parallel to the short-circuited stub
112 wherein a gap is formed between the open-circuited
113 stub and the short-circuited stub, and the open-circuited
114 stub comprises a first end and a second end in
115 which the first end is connected to the antenna part and
116 is corresponding to the open-circuited end of the
117 short-circuited stub such that the open-circuited stub
118 is coupled to the short-circuited stub.
119
120 2. The printed filtering antenna of claim 1, wherein an
121 equivalent circuit of the short-circuited stub and the
122 open-circuited stub comprises two groups of series-connected
123 inductor-capacitor (LC) resonators that are connected in parallel.
124
125 3. The printed filtering antenna of claim 2, wherein the two
126 groups of series-connected LC resonators generate two
127 transmission zeros at a band edge of the printed filtering antenna.
128
129 4. The printed filtering antenna of claim 3, wherein the two
130 groups of series-connected LC resonators are equivalent to a
131 single parallel-connected LC resonator at a resonant frequency
132 of the printed filtering antenna to generate a transmission pole.
133
134 5. The printed filtering antenna of claim 4, wherein when a
135 first electric length of the open-circuited stub and a second
136 electric length of the short-circuited stub are equal to π/2 at
137 the resonant frequency or each of the open-circuited stub and
138 the short-circuited stub is a quarter-wavelength circuit, and
139 the two transmission zeros are symmetric with respect to the
140 transmission pole.
141
142 6. The printed filtering antenna of claim 4, wherein when a
143 first electric length of the open-circuited stub and a second
electric length of the short-circuited stub are not equal, the
two transmission zeros are asymmetric with respect to the
transmission pole.

7. The printed filtering antenna of claim 1, wherein the
short-circuited stub and the open-circuited stub are two
micro-strips disposed on the same plane.

8. The printed filtering antenna of claim 1, wherein the
short-circuited stub is a coplanar waveguide (CPW) and the
open-circuited stub is a micro-strip, and a substrate is formed
in the gap between the short-circuited stub and the open-
circuited stub such that the short-circuited stub and the open-
circuited stub are on opposite sides of the substrate.

9. The printed filtering antenna of claim 8, wherein the
short-circuited stub is an extension of a ground surface.

10. The printed filtering antenna of claim 1, wherein the
short-circuited stub and the open-circuited stub are a slot line
or a coplanar stripline (CPS) respectively.

11. The printed filtering antenna of claim 1, wherein the
antenna part occupies an antenna area and the coupled line
resonator is formed in the antenna area.

12. The printed filtering antenna of claim 1, wherein the
antenna part is a monopole antenna, an F antenna or an
inverted-F antenna.

13. The printed filtering antenna of claim 1, wherein the
coupled line resonator has an N-th order such that the antenna
part is an N-th order antenna, in which each order of the
coupled line resonator is coupled to each other and one order
of the coupled line resonator is connected to the antenna part
directly.