MULTIPLEXED BI-DIRECTIONAL CIRCULATOR

Inventors: Rong-Yuan Chang, Hsinchu (TW); Fu-Chiarng Cheng, Hsinchu (TW)

Assignee: National Chiao Tung University, Hsinchu (TW)

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See application file for complete search history.

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Primary Examiner — Robert Pascal
Assistant Examiner — Kimberly Glenn

Attorney, Agent, or Firm — Morris Manning & Martin LLP, Tim Tingkang Xia, Esq.

ABSTRACT

In the present invention, a novel multi-port microwave circuit, also known as a multiple bi-directional circulator, is designed based upon the basis of the EBG characteristic of the metamaterials. Firstly, the concept of the traditional single-layered mushroom structure is extended with the suspending microstrip line to the multi-layered structure. In this way, the multi-layered structure can reveal multi-band EBG characteristic and achieve miniaturization. Moreover, we use three sets of proposed dual-band EBG circuit to be series-connected in a ring-type structure. By using proper impedance matching, the design of the multiple bi-directional circulator is accomplished. It combines the capabilities of the diplexer, the duplexer and the circulator. The triplex bi-directional circulator can integrate three kinds of communication systems with each other, which operates at frequencies comprising GSM 1800 MHz, WiFi 2.45 GHz, and WiMAX 3.5 GHz, respectively. It is suitable for the information integration of multi-band and multi-system communication applications.

12 Claims, 7 Drawing Sheets
\begin{align*}
\begin{bmatrix}
P_1 & P_2 & P_3 \text{ (Input)}
\end{bmatrix}
\begin{bmatrix}
0 & 1 & 0 & P_1 \\
0 & 0 & 1 & P_2 \\
1 & 0 & 0 & P_3 \\
\end{bmatrix}
\begin{bmatrix}
\text{Output}
\end{bmatrix}
\end{align*}

\text{FIG. 1D (Prior Art)}

\text{FIG. 1C (Prior Art)}
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8GHz</td>
<td>[0 1 0 0]</td>
</tr>
<tr>
<td>2.45GHz</td>
<td>[0 0 1 0]</td>
</tr>
<tr>
<td>3.5GHz</td>
<td>[1 0 0 1]</td>
</tr>
</tbody>
</table>

FIG. 5

$$[S] = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \end{bmatrix}$$
MULTIPLEXED BI-DIRECTIONAL CIRCULATOR

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD OF THE INVENTION

The present invention relates to a circulator, more particularly to, a multiplexed bi-directional circulator having a notch filter.

BACKGROUND OF THE INVENTION

System integration technology plays an important role for wireless communication development. And, a wireless communication capable of integrating a plurality of various communication frequency specifications is a popular research topic in recent years. Consequently, reliance of circuit design at the system integration side which enact the circuit exhibits a function of integrating a plurality of various communication specification is, therefore, the best candidate for this popular application. The most common circuit designs are demonstrated as follows:

FIG. 1A illustrates a duplexer 10a, comprises a first port 101a, a second port 102a, and a third port 103a; the first port 101a receives a first frequency f1, and outputs a second frequency f2a, the second port 102a outputs a first frequency f1a, and the third port 103a receives a second frequency f2a. Alternatively, the duplexer 10a is capable of bi-directional communication instead of frequency multiplexing.

FIG. 1B illustrates a duplexer 10b, comprises a first port 101b, a second port 102b, and a third port 103b; where the first port 101b receives a first frequency f1b, and a second frequency f2b, the second port 102b outputs a first frequency f1b, and the third port 103b outputs a second frequency f2b. That is to say, the duplexer 10b is capable of frequency multiplexing instead of bi-directional communication.

The duplexer 10a or the duplexer 10b either illustrated in FIG. 1A or FIG. 1B can be capable of either bi-directional or multiplexing. Alternatively, the circuit characterized in bi-direction cannot simultaneously function as multiplexing, and the circuit characterized in multiplexing cannot simultaneously function as bi-direction. For microwave circuits, this is due to the conventional design and failure to using globally matching network.

FIG. 1C illustrates a circulator 10c having three input/output ports (P1, P2, and P3). In view of its counter-clockwise direction, (clockwise direction related description is omitted thereto), its input/output matrix is denoted as [S] as illustrated in FIG. 1D, where its input is the matrix [S]'s vertical axis and its output is the matrix [S]'s horizontal axis, is a very conventional circuit for the modern communication system, which enacts the signal being transmitted in enclosed system but only single frequency/band is allowed thus the satisfaction for the modern communication system cannot be met.

SUMMARY OF THE INVENTION

In view of the disadvantages of prior art, the primary object of the present invention relates to disclose a circulator having loop communication capability and simultaneously characterized in bi-direction communication and multiplexing, capable of integrating the transmit and receive for at least three communication systems, where the systems comprise GSM 1800 MHz, WiFi 2.45 GHz, and WIMAX 3.5 GHz, to ensure the three systems being capable for mutual communication and data transmitting.

The present invention relates to a multiplexed bi-directional circulator, comprises: a first in/output port; a second in/output port; a first filter; a second filter; a third filter; and a transmission line, wherein the transmission line enacts the first in/output port; the second in/output port; and the third in/output port are linked in closed loop.

Further scope of applicability of the present application will become more apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description given herein below and the accompanying drawings which are given by way of illustration only, and thus are not limiting of the present invention and wherein:

FIG. 1A relates to a conventional duplexer circuit diagram;
FIG. 1B relates to a conventional duplexer circuit diagram;
FIG. 1C relates to a conventional circulator circuit diagram;
FIG. 1D relates to an in/output matrix diagram for the FIG. 1C;
FIG. 2 relates to a circulator according to one of the preferred embodiments of the present invention;
FIG. 3 relates to another circulator according to another one of the preferred embodiments of the present invention;
FIGS. 4A and 4B relates to a multiplex bi-directional circulator according to the present invention; and
FIG. 5 relates to three scattering parameter matrices according to the present invention.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

For your esteemed members of reviewing committee to further understand and recognize the fulfilled functions and structural characteristics of the invention, several exemplary embodiments cooperating with detailed description are presented as the follows:

FIG. 2 relates to a preferred embodiment of the present invention, exemplarily, the input signals are selected from the group consisting of 1800 MHz, 2.45 GHz, and 3.5 GHz. (But not limited thereto, the skilled artisan can vary the frequency by himself), a three-port circular microwave circuit 20 is disclosed, and a first port 201 is simultaneously the in/output port for GSM 1800 MHz and WiFi 2.45 GHz, and a second port 202 is simultaneously the in/output port for GSM 1800 MHz and WIMAX 3.5 GHz, and a third port 203 is simultaneously the in/output port for WiFi 2.45 GHz and WIMAX 3.5 GHz. As illustrated by FIG. 2, at the branch path of the closed loop 204 between the first port 201 and the second port 202, a first filter 207 is disposed for a notch circuit for WiFi 2.45 GHz and WIMAX 3.5 GHz. In the same manner, at the branch path of the closed loop 205 between the first port 201
and the third port 203, a second filter 208 is disposed for a notch circuit for GSM 1800 MHz and WiMAX 3.5 GHz. Finally, at the branch path of the closed loop 205 between the third port 203 and the second port 202, a third filter 209 is disposed for a notch circuit for Wi-Fi 2.45 GHz and GSM 1800 MHz.

Preferably, the aforementioned notch circuits can be of a double-layered mushroom structure. A three-port circular microwave circuit 30 is disclosed in FIG. 3, where a first port 301 is simultaneously the in/output port for GSM 1800 MHz and Wi-Fi 2.45 GHz, and a second port 302 is simultaneously the in/output port for GSM 1800 MHz and WiMAX 3.5 GHz, and a third port 303 is simultaneously the in/output port for Wi-Fi 2.45 GHz and WiMAX 3.5 GHz. As illustrated in FIG. 3, a double-layered mushroom structure is disposed at the branch path of the closed loop 304 between the first port 301 and the second port 302 and serving as an EBIC circuit 307 (electromagnetic band-gap) for Wi-Fi 2.45 GHz and WiMAX 3.5 GHz, and accordingly an appropriate position at the branch path for the mushroom structure is found for impedance match of the whole circuit. In the same manner, at the branch path of the closed loop between the first port 301 and the second port 303 and an EBIC circuit 308 (electromagnetic band-gap) serves for GSM 1800 MHz and WiMAX 3.5 GHz, and accordingly an appropriate position at the branch for the mushroom structure is found for impedance match of the whole circuit. Finally, at the branch path of the closed loop between the first port 302 and the second port 303 and an EBIC circuit 309 (electromagnetic band-gap) serves for GSM 1800 MHz and Wi-Fi 2.45 GHz, and accordingly an appropriate position at the branch for the mushroom structure is found for impedance match of the whole circuit.

Preferably, the appropriate position is selected from the quartered-wavelength (or its integer multiple) of the signals received at the neighboring in/output ports at the branch for the EBIC circuits 307, 308, and 309. Preferably, the closed loop 304 and the double-layered mushroom structure are respectively disposed on three substrates, and there is an air space between three substrates. Preferably, the closed loop 304 is a micro-strip structure. Preferably, the closed loop 304 is selected from the shapes of rectangular, triangle, and circular. Preferably, the mushroom structure is made of a metal. Preferably, the size of the metal can determine the impedance match of the circulator 30.

The circuit diagram for a multiplexer bi-directional circulator 40 is illustrated in FIG. 4A, between a first port 401 and a second port 402, there is disposed an EBIC circuit 407 for 2.45 GHz and 3.5 GHz and thus only GSM 1800 MHz signal is permitted for running through, which means the signal channel between the first port 401 and the second port 402 is GSM 1800 MHz channel. Also, between the first port 401 and a third port 403, there is disposed an EBIC circuit 408 for 1.8 GHz and 3.5 GHz and thus only Wi-Fi 2.45 GHz signal is permitted for running through, which means the signal channel between the first port 401 and the third port 403 is Wi-Fi 2.45 GHz channel. Additionally, since two EBIC circuits 407 and 408 are both for the band for 3.5 GHz, thus, the WiMAX 3.5 GHz signals are both blocked out, and cannot be transmitted from the second port 402 and third port 403 from the first port 401. In the similar manner, WiMAX 3.5 GHz signal cannot be transmitted to the first port 401 from the second port 402 and the third port 403, hence, the first port 401 can also be deemed as an isolated port for WiMAX 3.5 GHz.

In the similar manner, operation between the port 402 and the port 403 can be derived accordingly. Since both of them are coupled to two sets of multiplexed EBG circuits and the second port 402 can only permits GSM 1800 MHz and WiMAX 3.5 GHz signals being transmitted to the first port 401 and the third port 403. Meanwhile, the third port 403 can only permits the Wi-Fi 2.45 GHz and WiMAX 3.5 GHz signals being respectively transmitted to the first port 401 and the second port 402. Additionally, the second port 402 and the third port 403 cannot transmit/receive the Wi-Fi 2.45 GHz and GSM 1.8 GHz signals, therefore, the 402 and 403 are respectively the isolation port for Wi-Fi 2.45 GHz and GSM 1.8 GHz signals.

Due to the impedance match, the circulator 40 has an gap between elements, which is selected from the quartered-wavelength of the signals received at the neighboring in/output ports at the branch for the EBIC circuits 407, 408, and 409, for example, when the branch of the loop 404 is measured as 2.3 cm as its radius, the neighboring distance for the in/output port of EBG 407, 408 and 409 are 2.639, 1.955, 4.203, 2.1 3.91, 2.786 (cm, but not limited thereto).

Referring now to FIG. 4B, which is a partial sectional view of FIG. 4A, the notch circuits can be a double-layered mushroom structure. The double-layered mushroom structure is disposed at the branch path of the closed loop 404 between the first port 401 and the second port 402. Preferably, the closed loop 404 and the double layered mushroom structure are respectively disposed on three substrates 413a, 413b and 413c, and there is an air gap 414 between the three substrates 413. The first metallic patch 411 (square in FIG. 4A) is overlaid on the second metallic patch 412 (square in FIG. 4A), and the transmission line, i.e., closed loop 404, is located on top of the first metallic patch 411 and the second metallic patch 412, which accordingly form a mushroom structure. Further, the three substrates 413a, 413b and 413c are located between the transmission line loop 404, the first metallic patch 411, the second metallic patch 412, and the ground line 410, and an air gap 414 is located between the substrate 413a and the first metallic patch 411.

Finally, all the scattering parameters for the multiplexer bi-directional circulator are adjusted and three scattering parameter matrixes are used to describe the characteristics for the microwave circuit, as illustrated in FIG. 5. By means of the scattering parameter matrix, the skilled artisan can readily understand the circuit characteristics under the operations for GSM 1800 MHz, WiFi 2.45 GHz, and WiMAX 3.5 GHz, which is suitable for the user to operate under different modes. The aforesaid circulator can be disposed in a system intersection, which is desirable to be integrated for three different communication specs in different bands. The circulator can be designed for GSM 1.8 GHz, WiFi 2.45 GHz, and WiMAX 3.5 GHz, and we can hook up the GSM and Wi-Fi at the first port, and GSM and WiMAX are hooked at the second port, and WiFi and WiMAX are hooked up at the third port, hence, a skilled artisan can successful to ensure the three systems capable of mutually transmitting their data. And the same concept can be designed for other different communication specs or even widely applied to more bands.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the invention in include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed readily apparent and obvious to one skilled in
the art, and all equivalent relationships to those illustrated in
the drawings and described in the specification are intended to
be encompassed by the present invention.

What is claimed is:

1. A multiplexed bi-directional circulator, comprising
a first in/output port;
a second in/output port;
a third in/output port;
a first filter, coupled to the first in/output port and the
second in/output port;
a second filter, coupled to the third in/output port and the
second in/output port;
a third filter, coupled to the first in/output port and the third
in/output port; and
a transmission line, wherein the first in/output port, the
second in/output port, and the third in/output port are
linked by the transmission line via the first, second and
third filters in closed loop,
wherein the first filter, the second filter, and the third filter
are characterized in electromagnetic band-gap structure.

2. The circulator as recited in claim 1, wherein there is a
first distance between the second in/output port and the sec-
ond filter, and a second distance between the first in/output
port and the third filter, when a first signal is permitted for
running through between the first in/output port and the sec-
ond in/output port, the first distance and the second distance
are assigned to be a quarter of wavelength of the first signal
received at the in/output ports;
wherein there is a third distance between the first in/output
port and the first filter, and a fourth distance between the
third in/output port and the second filter, when a second
signal is permitted for running through between the first
in/output port and the third in/output port, the third dis-
tance and the fourth distance are assigned to be a quarter
of wavelength of the second signal received at the in/output
ports;
wherein there is a fifth distance between the third in/output
port and the third filter, and a sixth distance between the
second in/output port and the first filter, when a third
signal is permitted for running through between the sec-
ond in/output port and the third in/output port, the fifth
distance and the sixth distance are assigned to be a
quarter of wavelength of the third signal received at the
in/output ports.

3. The circulator as recited in claim 1, wherein the first
filter, the second filter, and the third filter are characterized in
multiple-layered mushroom structure.

4. The circulator as recited in claim 3, wherein the closed-
loop transmission line and the filters with the mushroom
structure are respectively disposed on three substrates.

5. The circulator as recited in claim 4, wherein the three
substrates further comprises an air gap in between.

6. The circulator as recited in claim 3, wherein the mush-
room structure is made of metal.

7. The circulator as recited in claim 6, wherein a impedance
match in the circulator is determined up to the size of the
metal.

8. The circulator as recited in claim 1, further comprising a
Nth in/output port and a Nth filter; wherein the first filter, . . .
Nth filter are of N-1 layered mushroom structure, and N is an
integer greater than 3.

9. The circulator as recited in claim 1, wherein the closed-
loop transmission line is characterized in micro-strip struc-
ture.

10. The circulator as recited in claim 1, wherein the closed-
loop transmission line has a shape selecting from the group
consisting of rectangular, triangular, or circular.

11. The circulator as recited in claim 1, wherein signals at
in/output ports are selecting from a group consisting of 1800
MHz, 2.45 GHz, and 3.5 GHz.

12. The circulator as recited in claim 1, wherein, the first
filter, the second filter or the third filter is a notch filter.

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