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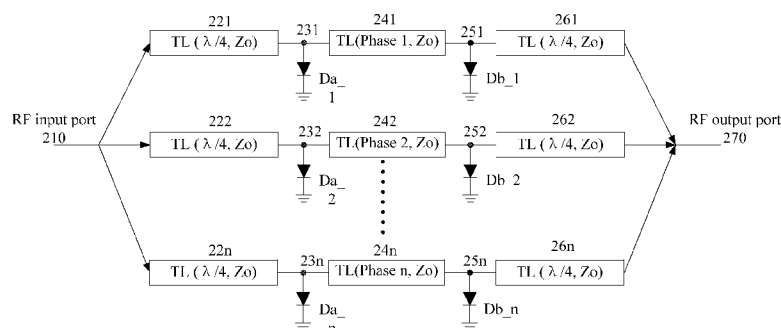


Fig. 2

(57) Abstract: The present invention relates to a phase shifter for high power signal simplifying circuit and a method for shifting phase, the shifter comprises: at least two different RF signal transmission paths between an input port and an output port of the phase shifter., wherein, each transmission path is to cause different phase delay to the RF signal passing through the path; selecting units, connected to fee transmission pa tits respectively, for selecting for the RF signal from the at least two transmission paths a transmis-sion path, through which the RF signal is practically to pass. A stepping phase shifter applicable for high power signal is provided. Phase shifting is implemented by controlling the selecting troit, which has an advantage of convenient operations, and the manufac-ture cost is reduced by using the transmission line as the phase delay unit.



A PHASE SHIFTER FOR HIGH POWER SIGNAL AMPLIFYING CIRCUIT AND A METHOD FOR SHIFTING PHASE

FIELD OF THE INVENTION

5 The present invention relates to a phase shifter for high power signal amplifying circuit and a method for shifting phase in a high power signal amplifying circuit.

BACKGROUND OF THE INVENTION

10 The phase adjustment of high power signal is needed to solve the phase difference of the signal resulting from the combination of signals in a plurality of high power paths in the circuit.

15 The reflection-type phase shifter is often used to adjust phase of the signal paths in the circuits. The reflection-type phase shifter employs a quadrature coupler and varactor diodes to shift the phase delay in the signal path. Fig. 1 shows a block diagram of the phase shifter in the prior art. The phase shifter comprises a 3dB quadrature coupler 110, the four ports of which are RF input port 111, coupled port 112, direct port 113, and isolated port 114. The RF input port 111 is connected to the RF input signal, the coupled port 112 and the direct port 113 are connected to the ground via varactor diodes 120 and 130. The capacities of the varactor diodes 120 and 130 could be adjusted by the offset voltage (not shown) connected to the coupled port 112 and the direct port 113, thus the phase shift of the signal passing through the coupled port 112 and the direct port 113 is adjusted. When the signal passing through the coupled port 112 and the direct port 113 are respectively reflected from the ground terminal to the coupled port 112 and the direct port 113, the signal components caused by the reflected signals are balanced out at the RF input port 111. 20 The signal components caused by the reflected signals are overlapped at the isolated port 114 to form the RF output signal. In comparison with the input signal at the RF input port 111, the output signal has a phase difference determined by the varactor diode, whereby the function of phase adjustment is implemented. However, the varactor diode is not applicable for the high power signal, which limits its application in high power scene.

30 On the other hand, the signal transmission line can be used as phase shifter for high power path. However due to the fact that the lengths of transmission lines are fixed and hard to be changed after the wiring is finished, the application of signal transmission line as the phase shifter is limited.

SUMMARY OF THE INVENTION

One object of the present invention is to provide a phase shifter applicable for high power signal, which implements stepping adjustable phase shift by selecting different transmission line. It is very advantageous.

5 According to one aspect of the present invention, it is provided a phase shifter for high power signal amplifying circuit, comprising: at least two different RF signal transmission paths between an input port and an output port of the phase shifter, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path; and selecting units, connected to the transmission paths respectively, for selecting
10 for the RF signal from the at least two transmission paths a transmission path through which the RF signal is practically to pass. According to this aspect, it is applicable for applications at high power scene that using signal transmission line to adjust phase; furthermore, providing a plurality of transmission paths and selecting units can provide variable phase delay adjustment.

15 Further, each transmission path is parallel connected between the input port and the output port, each transmission path comprising respectively: a first isolating unit (221, 222, 22n) configured between the input port and a first node(231, 232, 23n), for making the signal between the input port and the first node being 0 when the first node is connected to the ground; a second isolating unit (261, 262, 26n) configured between the output port and
20 a second node(251, 252, 25n), for making the signal between the output port and the second node being 0 when the second node is connected to the ground; a transmission line (241, 242, 24n) with a certain length between the first node and the second node, for causing a corresponding phase delay to the RF signal passing through the transmission line; each transmission line in each transmission path having different length corresponding to
25 different phase delay. This further embodiment provides a more specific embodiment of the present invention, which has an advantage of being capable of letting through higher power (highest power among all the embodiments in this description).

Or further, the phase shifter comprises: a 3dB quadrature coupler (410), whose input port (411) is used as the input port of the phase shifter for connecting the RF input
30 signal, and the isolated port (414) of the 3dB quadrature coupler being used as the output port of the phase shifter; a first transmission line and a second transmission line, respectively connecting the coupled port (412) and the direct port (413) of the 3dB quadrature coupler to the ground, and having at least two nodes (431, 432, 43N and 451, 452, 45N) configured thereon; the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase
35 2+Phase N) of the RF signal between the coupled port and each node on the first transmission line being equal to the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N) of the RF signal between the direct port and the corresponding node on

the second transmission line; the at least two different RF signal transmission paths comprising the paths from the coupled port to the corresponding node (one of 431, 432, 43N) and from the direct port to the corresponding node (one of 451, 452, 45N), corresponding to the correspondence phase delay (Phase 1, Phase 1+Phase 2, Phase 1+Phase 2+Phase N) from the coupled port and the direct port to each node. This further embodiment provides a more specific embodiment of the present invention, which has an impact contracture, and less material is needed for the transmission line.

According to another aspect of the present invention, it is provided a method for shifting phase in a high power signal amplifying circuit, comprising: providing at least two different RF signal transmission paths, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path; selecting for the RF signal from the at least two transmission paths a transmission path through which the RF signal is practically to pass.

A stepping phase shifter applicable for high power signal is provided by the solution in the present invention. Phase adjustment is implemented by controlling the selecting units, which has an advantage of convenient operation. The manufacture cost is reduced by using transmission line as the phase delay unit.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, preferred embodiments of the present invention will be described by using examples in connection with the following figures:

Fig. 1 shows a block diagram of the circuit of the phase shifter in the prior art;

Fig. 2 shows a block diagram of the circuit of the phase shifter for high power signal amplifying circuit according to one embodiment of the present invention;

Fig. 3A and 3B show the block diagrams of the alternative circuits of the isolating unit of the phase shifter in the embodiment in Fig. 2;

Fig. 4 shows a block diagram of the circuit of the phase shifter for high power signal amplifying circuit according to another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

A phase shifter for high power signal amplifying circuit according to the present invention, comprising:

at least two different RF signal transmission paths between an input port and an

output port of the phase shifter, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path; and

selecting units, connected to the transmission paths respectively, for selecting for the RF signal from the at least two transmission paths a transmission path through which the RF signal is practically to pass.

Two embodiments of the phase shifter will be illustratively described in the following, wherein different mechanisms are used to implement the at least two different RF signal transmission paths and the selecting units. It could be understood that, the scope of the invention is not limit thereto, and the at least two different RF signal transmission paths and selecting units, implemented in other manners without departing from the spirit and scope of the claims, fall in to the scope of the invention.

Fig. 2 shows a block diagram of the circuit of the phase shifter for high power signal amplifying circuit according to one embodiment of the present invention. As shown in the figure, n different transmission paths are configured between RF input port 210 and RF output port 270, wherein 3 of them are shown in the figure. The 3 transmission paths are: a first transmission path, from the RF input port 210 through the first isolating unit 221, the first node 231, the transmission line 241 that cause a phase delay of Phase 1 to the signal, the second node 251 and the second isolating unit 261 to the RF output port 270; a second transmission path, from the RF input port 210 through the first isolating unit 222, the first node 232, transmission line 242 that cause a phase delay of Phase 2 to the signal, the second node 252 and the second isolating unit 262 to the RF output port 270; and a n-th transmission path, from RF input port 210 through the first isolating unit 22n, the first node 23n, transmission line 24n that cause a phase delay of Phase n to the signal, the second node 25n and the second isolating unit 26n to the RF output port 270. Other transmission paths between the RF input port 210 and the RF output port 270 are configured as similar configurations. All these different transmission paths can cause different phase delay to the RF signal while the signal is passing through the transmission path. Furthermore, it can be understood by those skilled in the art that, other quantity of transmission path, for example, two transmission paths, could be configured.

In this embodiment, selecting units are configured on each transmission path respectively. The first isolating units 221, 222, 22n on each transmission path cooperate respectively with the selecting units connected to the first node 231, 232, 23n, while the second isolating units 261, 262, 26n on each transmission path cooperate respectively with the selecting units connected to the second node 251, 252, 25n, which serves as transmission path selection.

For example, in this embodiment, the first and second isolating units are all transmission line with its length being a quarter of wave length of the input RF signal. The

selecting units are specifically PIN diodes Da_1, Db_1, Da_2, Db_2,, Da_n, Db_n. For example, the first transmission path is to cause a phase shift of Phase $1+\pi$ to the RF signal. Now in order to cause a phase shift of Phase $1+\pi$ to the input RF signal, the control circuit (not shown) needs to select the first transmission path. For this purpose, the PIN diode Da_1 and Db_1 are configured to be in open status, and the PIN diode on the other transmission path Da_2, Db_2,, Da_n, Db_n are configured to be in short circuit status. The first transmission path is thereby selected, while other transmission paths all could be considered as open circuit.

When for example the PIN diode connected to the first node 232 on the second transmission path is in short circuit status, the first node 232 is directly connected to the ground. The signal input through the RF input port 210 is reflected on the first node after being transmitted over the transmission line having a length of a quarter of the wave length. The reflected signal is overlapped with the input signal, which leads to a final signal being 0. Thus the signal between the input port and the first node is 0. Likely, the second isolating unit 262 cooperates with the PIN diode at the second node, so as to make the signal between the second node 252 and the RF output port 270 to be 0. Thus the second transmission path could be considered as open circuit. Meanwhile, the PIN diodes in the first transmission path are under open circuit status, which enables the signal input through RF input port 210 to pass through the first isolating unit 221, the first node 231, the transmission line 241 that cause a phase delay of Phase 1 to the signal, the second node 251 and the second isolating unit 261 to the RF output port 270. In comparison with the signal input through the input port 210, the output signal at the RF output port 270 has a phase delay of Phase $1+\pi$.

Fig 3A and 3B shows the block diagrams of alternative circuits of the isolating unit of the phase shifter in the embodiment in Fig. 2. The isolating unit in Fig. 2 is a transmission line with its length being a quarter of wave length of the input RF signal. Alternatively, the isolating unit could be π lumped network as shown in Fig. 3A or T lumped network as shown in Fig. 3B. The corresponding transmission path could be selected according to the practical requirement, by the cooperation between the isolating unit with the selecting units.

Fig. 4 shows a block diagram of the circuit of the phase shifter for high power signal amplifying circuit according to another embodiment of the present invention. In this embodiment, there is a 3dB quadrature coupler, whose input port 411 is used as the input port of the phase shifter for connecting a RF input signal, and the isolated port 414 of the 3dB quadrature coupler is used as the output port of the phase shifter. The coupled port 412 and the direct port 413 of the 3dB quadrature coupler are connected to the ground through a first transmission line and a second transmission line, having respectively at least two nodes 431, 432, 43N and 451, 452, 45N configured on the first second transmission line.

The length of the transmission line between the coupled port 412 and the first node 431 on the first transmission line equals to the length of the transmission line between the direct port 413 and the first node 451 on the second transmission line, being the length of a transmission line that causes a phase shift of Phase 1 to the signal. Correspondingly, the phase delay Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N of the RF signal between the coupled port 412 and each node on the first transmission line equals to the phase delay Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N of the RF signal between the direct port 413 and the corresponding node on the second transmission line.

In this embodiment, at least 3 different RF signal transmission path are comprised: the paths from the coupled port to the corresponding node (one of 431, 432, 43N) and from the direct port to the corresponding node (one of 451, 452, 45N), corresponding to the correspondence phase delay Phase 1, Phase 1+Phase 2, Phase 1+Phase 2+Phase N from the coupled port 412 and the direct port 413 to each node.

For example, for causing a phase shift of $\pi/2-2*\text{Phase 1}$ to the input RF signal, the control circuit (not shown) may select the first transmission path. Specifically, the control circuit configures the PIN diode Da_1 which is connected to the first node 431 on the first transmission line and the PIN diode Db_1 which is connected to the first node 451 on the second transmission line to be in short circuit status, and configures the PIN diodes on the other nodes Da_2, Db_2,, Da_N-1, Db_N-1, Da_N, Db_N to be in open circuit status. The selection of the first transmission path, which corresponds to the phase delay of $\pi/2-2*\text{Phase 1}$ and on the one hand passes through the coupled port 412 to the first node 431 on the first transmission line, and on the other hand passes through the direct port 413 to the first node 451 on the second transmission line, is thereby implemented.

The signal is input through the RF input port 411, and on the one hand passes through the coupled port 412, the transmission line 421 that causes a phase delay of Phase 1 to the signal on the first transmission line, to the node 431; and on the other hand passes through the direct port 413, the transmission line 441 that causes a phase delay of Phase 1 to the signal on the second transmission line, to the node 451. Because the diodes Da_1 and Db_1 are in short circuit status, the signals are reflected after arriving at the node 431 and 451, and are fed in to the coupled port 412 and the direct port 413 respectively after passing through the transmission lines 421, 441 that cause a phase delay of Phase 1 to the signal. The signal components caused by the reflected signals are canceled out at input port 411 after overlapping, while the signal components caused by the reflected signals form the RF output signal at the isolated port 414 after overlapping.

Similarly, for causing a phase shift of $\pi/2-2*(\text{Phase 1}+\text{Phase 2})$ to the signal, the control circuit could select the second transmission path. Specifically, the control circuit configures the PIN diode Da_2 which is connected to the second node 432 on the first

transmission line and the PIN diode Db_2 which is connected to the second node 452 on the second transmission line to be in short circuit status, while the other PIN diodes Da_1, Db_1,, Da_N-1, Db_N-1, Da_N, Db_N are configured to be in open circuit status, thus, a phase shift of $\pi/2-2*(\text{Phase 1}+\text{Phase 2})$ can be caused to the signal.

5 It can be understood, the number of nodes on the first and second transmission line is no limited, and could be configured flexibly by those skilled in the art, for example being configured according to the granularity of the phase adjustment.

Those skilled in the art may also come to the idea of using switch or other selecting unit that can achieve the function of signal path selection, so as to select different
10 phase delay and thus enable a stepping adjustment of the phase of the input signal.

Furthermore, a method for shifting phase in a high power signal amplifying circuit is proposed in the invention. The method comprises: providing at least two different RF signal transmission paths, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path; selecting for the RF signal from the at least two
15 transmission paths a transmission path, through which the RF signal is practically to pass.

Further, the step of providing transmission paths comprises providing parallel connected transmission paths, for each transmission path respectively: configuring a first isolating unit 221, 222, 22n between the input port for the RF signal and a first node 231, 232, 23n, for making the signal between the input port and the first node being 0 when the
20 first node is connected to the ground; configuring a second isolating unit 261, 262, 26n between the output port for the RF signal and a second node 251, 252, 25n, for making the signal between the output port and the second node being 0 when the second node is connected to the ground; configuring a transmission line 241, 242, ..., 24n having a certain length between the first node and the second node, for causing a corresponding phase delay
25 to the RF signal passing through the transmission line; each transmission line in each transmission path having different length corresponding to different phase delay.

Further, the step of selecting comprises: for selecting a certain transmission path, isolating the first and the second node, for example 231 and 251, of the transmission path from the ground, and connecting the first and the second nodes corresponding to other
30 transmission path except the transmission path to the ground, for example, connecting 232, 252,, 23n, 25n to the ground.

Furthermore, the method further comprises: providing a 3dB quadrature coupler, whose input port 411 is connected to the input RF signal, and the isolated port 414 of the 3dB quadrature coupler being used as the output port of the RF signal; providing a first
35 transmission line and a second transmission line, connecting respectively the coupled port 412 and the direct port 413 of the 3dB quadrature coupler to the ground, and configuring at

least two nodes 431, 432, 43N and 451, 452, 45N respectively on the first and second transmission line; the phase delay of the RF signal between the coupled port and each node on the first transmission line being equal to the phase delay of the RF signal between the direct port and the corresponding node on the second transmission line; the at least two
5 different RF signal transmission paths comprising the paths from the coupled port to the corresponding node and from the direct port to the corresponding node, corresponding to the phase delay respectively.

Further, the selecting step comprises: for selecting a certain phase delay, connecting the corresponding nodes corresponding to the phase delay on the first and
10 second transmission lines to the ground, while isolating the other nodes from the ground.

Those skilled in the art could readily appreciate that, the present invention is not limited to the details of the exemplary embodiments above. Other embodiments could be used to implement the present invention without departing from the spirit or basic features of the invention. Thus, the embodiments should be considered as exemplary and
15 non-limiting. Furthermore, in the claims, the term of “comprise” does not exclude the existence of other device(s) or step(s); and indefinite article “a/an” does not exclude the “multiple” case.

CLAIMS

1. A phase shifter for high power signal amplifying circuit, comprising:

- at least two different RF signal transmission paths between an input port and an output port of the phase shifter, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path;

- selecting units, connected to the transmission paths respectively, for selecting for the RF signal from the at least two transmission paths a transmission path, through which the RF signal is practically to pass.

2. A phase shifter according to Claim 1, wherein, each transmission path is parallel connected between the input port and the output port, and each transmission path comprising respectively:

a first isolating unit (221, 222, 22n) configured between the input port and a first node (231, 232, 23n), for making the signal between the input port and the first node being 0 when the first node is connected to the ground;

a second isolating unit (261, 262, 26n) configured between the output port and a second node (251, 252, 25n), for making the signal between the output port and the second node being 0 when the second node is connected to the ground;

a transmission line (241, 242, 24n) with a certain length between the first node and the second node, for causing a corresponding phase delay to the RF signal passing through the transmission line;

each transmission line in each transmission path having different length corresponding to the different phase delay.

3. A phase shifter according to Claim 2, wherein, the first isolating unit comprises any one of:

a transmission line with its length being a quarter of the wave length of the RF signal that is to be transmitted;

a π or T lumped network.

4. A phase shifter according to Claim 2 or 3, wherein, the selecting units comprises for each transmission path respectively:

a first diode for connecting the first node to the ground;

a second diode for connecting the second node to the ground.

5. A phase shifter according to Claim 4, wherein, the first diode and the second diode are PIN diodes.

6. A phase shifter according to Claim 4, further comprising:

- a control circuit, connected to each of the first and the second diodes, for controlling the selecting units to select from the at least two transmission paths a transmission path, through which the RF signal is practically to pass, according to a practical need of the phase delay;

for selecting a certain transmission path, switching off the first and the second diode that are connected to the certain transmission path, and switching on and connecting to the ground the first and the second diodes that are connected to other transmission paths except the certain transmission path.

7. A phase shifter according to Claim 1, further comprising:

- a 3dB quadrature coupler (410), whose input port (411) is used as the input port of the phase shifter for connecting a RF input signal, and the isolated port (414) of the 3dB quadrature coupler being used as the output port of the phase shifter;

- a first transmission line and a second transmission line, respectively connecting the coupled port (412) and the direct port (413) of the 3dB quadrature coupler to the ground, and having at least two nodes (431, 432, 43N and 451, 452, 45N) configured thereon;

the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N) of the RF signal between the coupled port and each node on the first transmission line being equal to the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N) of the RF signal between the direct port and the corresponding node on the second transmission line;

the at least two different RF signal transmission paths comprising the paths from the coupled port to the corresponding node (one of 431, 432, 43N) and from the direct port to the corresponding node (one of 451, 452, 45N), corresponding to the correspondence phase delay (Phase 1, Phase 1+Phase 2, Phase 1+Phase 2+Phase N) from the coupled port and the direct port to each node.

8. A phase shifter according to Claim 7, wherein, the selecting unit comprises:

a plurality of diodes (Da_1, Da_2, Da_N), connecting each node on the first transmission line to the ground respectively, and a plurality of diodes (Db_1, Db_2, Db_N) , connecting the corresponding node on the second transmission line to the ground respectively.

9. A phase shifter according to Claim 8, wherein, the plurality of diodes are PIN diodes.

10. A phase shifter according to Claim 8 or 9, further comprising:

- a control circuit, connected to each of the first and the second diodes, for controlling the selecting units to select from the at least two transmission paths a transmission path, through which the RF signal is practically to pass, according to a practical need of the phase delay;

- 5 for selecting a certain phase delay, switching on and connecting the diodes connected on the corresponding nodes corresponding to the phase delay on the first and second transmission lines to the ground, and switching off other diodes. .

11. A method for shifting phase in a high power signal amplifying circuit, comprising:

- 10 providing at least two different RF signal transmission paths, wherein, each transmission path is to cause different phase delay to the RF signal passing through the path;

selecting for the RF signal from the at least two transmission paths a transmission path, through which the RF signal is practically to pass.

12. A method according to Claim 11, wherein, the step of providing the transmission paths comprises providing parallel connected transmission paths, and for each transmission path respectively:

configuring a first isolating unit between the input port for the RF signal and a first node(231, 232, 23n), for making the signal between the input port and the first node being 0 when the first node is connected to the ground;

- 20 configuring a second isolating unit between the output port for the RF signal and a second node(251, 252, 25n), for making the signal between the output port and the second node being 0 when the second node is connected to the ground;

- 25 configuring a transmission line having a certain length between the first node and the second node, for causing a corresponding phase delay to the RF signal passing through the transmission line;

each transmission line in each transmission path having a different length corresponding to the different phase delay.

13. A method according to Claim 12, wherein, the step of selecting comprises:

- 30 for selecting a certain transmission path, isolating the first and the second node of the transmission path from the ground, and connecting the first and the second nodes corresponding to the other transmission path except the transmission path to the ground.

14. A method according to Claim 11, further comprising the following steps:

providing a 3dB quadrature coupler (410), whose input port (411) is connected to the

input RF signal, and the isolated port (414) of the 3dB quadrature coupler being used as the output port of the RF signal;

the step of providing the transmission paths provides a first transmission line and a second transmission line, respectively connecting the coupled port (412) and the direct port (413) of the 3dB quadrature coupler to the ground, and configures at least two nodes (431, 432, 43N and 451, 452, 45N) respectively on the first and second transmission line;

the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N) of the RF signal between the coupled port and each node on the first transmission line being equal to the phase delay (Phase 1, Phase 1+Phase 2, Phase 1+ Phase 2+Phase N) of the RF signal between the direct port and the corresponding node on the second transmission line;

the at least two different RF signal transmission paths comprising the paths from the coupled port to the corresponding node (one of 431, 432, 43N) and from the direct port to the corresponding node (one of 451, 452, 45N), corresponding to the correspondence phase delay (Phase 1, Phase 1+Phase 2, Phase 1+Phase 2+Phase N) from the coupled port and the direct port to each node.

15. A method according to Claim 14, wherein, the selecting step comprises:

for selecting a certain phase delay, connecting the corresponding nodes corresponding to the phase delay on the first and second transmission lines to the ground, while isolating the other nodes from the ground.

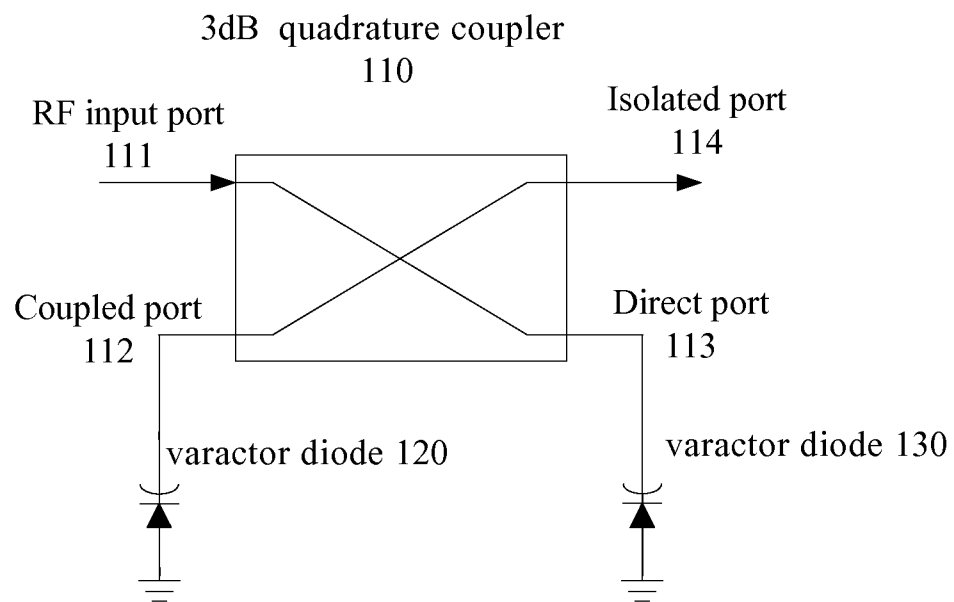


Fig. 1

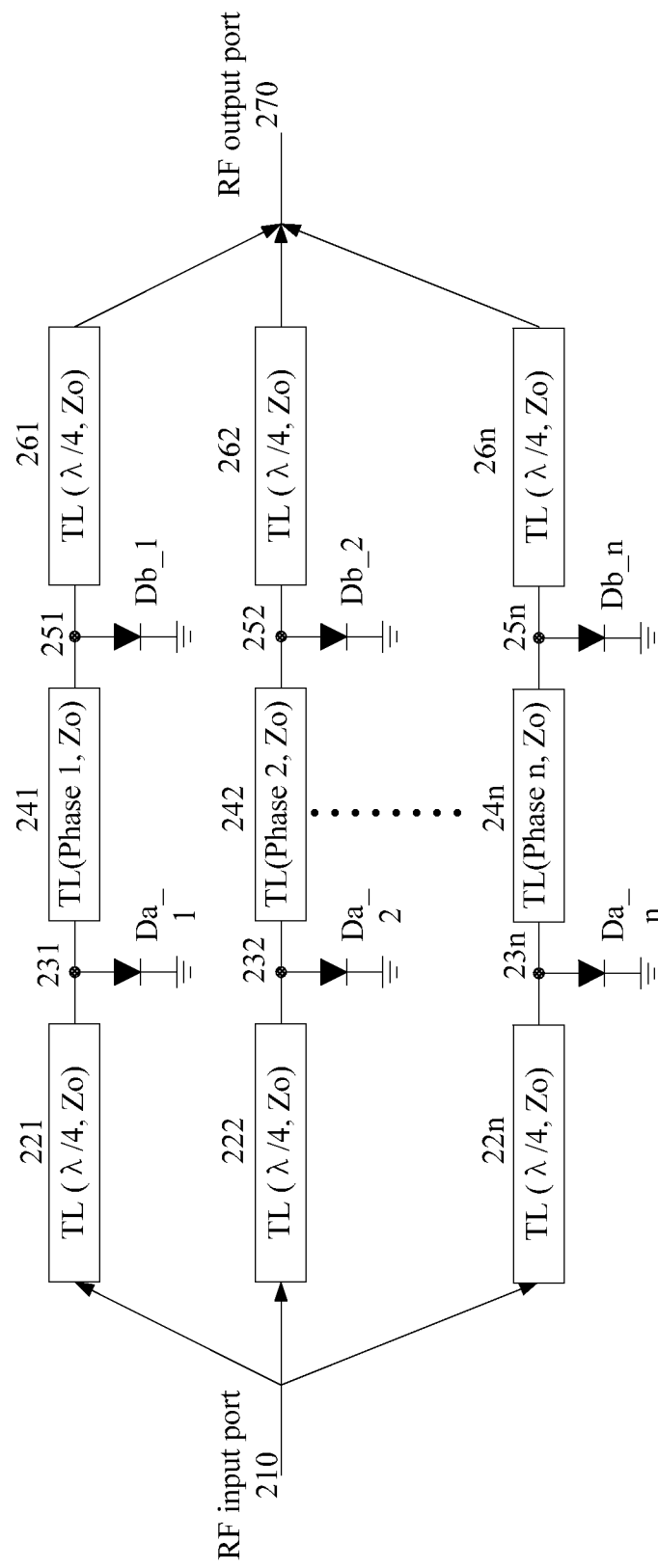


Fig. 2

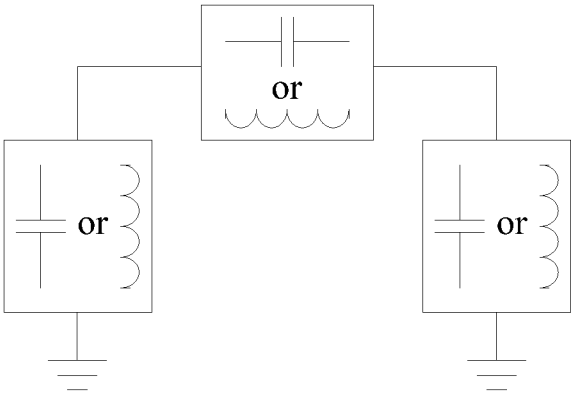


Fig. 3A

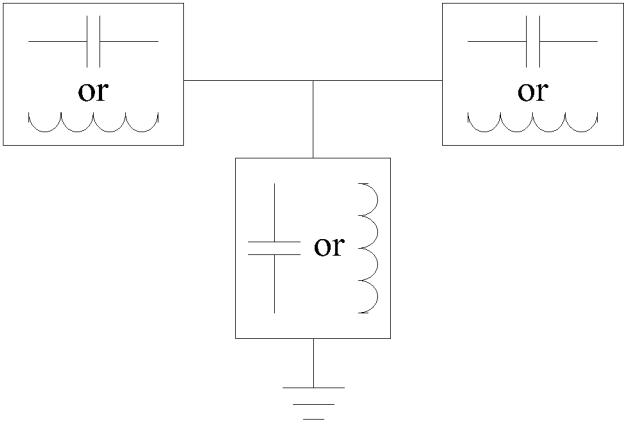


Fig. 3B

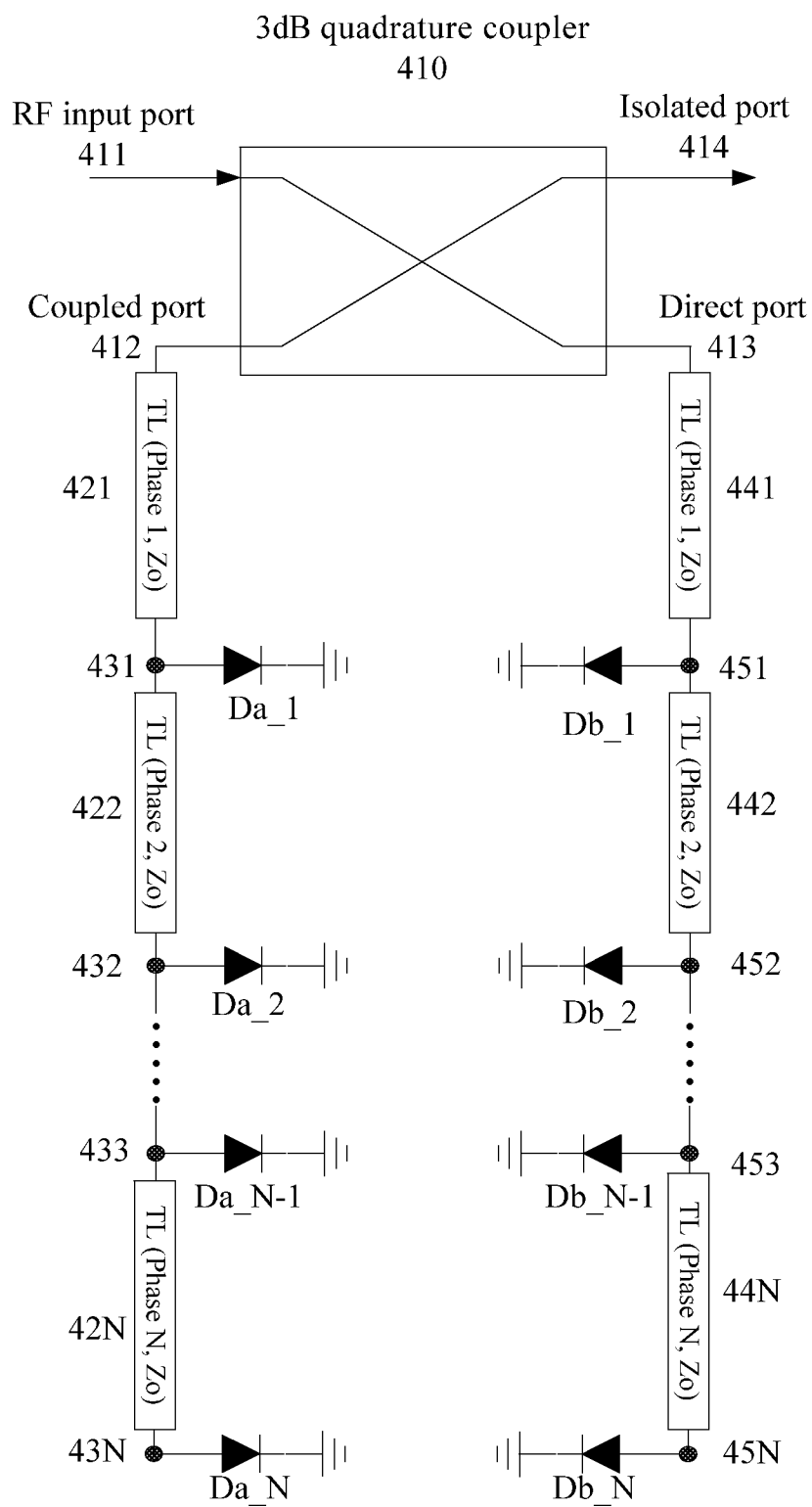


Fig. 4