BYPASS PATH LOSS REDUCTION

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 61/986,556, filed April 30, 2014 and titled "BYPASS PATH LOSS REDUCTION", the entire technical disclosure of which is herein incorporated by reference in its entirety.

BACKGROUND

Technical Field

[0002] This disclosure relates to electronic systems and, in particular, to radio frequency (RF) electronics.

Description of the Related Technology

[0003] A radio frequency (RF) system can include antennas for receiving and/or transmitting RF signals. There can be several components in an RF system that may access the antennas. For example, an RF system can include different transmit and/or receive paths associated with different frequency bands, different communication standards and/or different power modes, and each path may access a particular antenna at certain instances in time.

[0004] An antenna switch module can be used to electrically connect an antenna to a particular transmit or receive path of the RF system, thereby allowing multiple components to access the antennas. In certain configurations, an antenna switch module is in communication with a diversity module, which processes signals received and/or transmitted using one or more diversity antennas. The diversity module can include a bypass path that bypasses the receive path and/or transmit path processing of signals in the diversity module.

SUMMARY

[0005] For various embodiments below, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of various embodiments, some prominent features will now be briefly described.

[0006] One aspect of this disclosure is an electronic device with bypass path loss reduction, the electronic device comprising: a first switch having at least two throws; a second switch having at least two throws; a bypass path electrically connecting the first switch and the second switch; a receive path including a low noise amplifier, the receive path and the bypass path being connected to different throws of the first switch, and the receive path and the bypass path being connected to different throws of the second switch; and at least one inductor configured to compensate for an off state capacitance associated with at least one throw of the first switch that is unconnected to the bypass path to cause insertion loss of the bypass path to be reduced.

In an embodiment, an apparatus is provided that includes, a first switch having at least two throws, a second switch having at least two throws, a bypass path electrically connecting the first switch and the second switch, and at least one inductor configured to compensate for a capacitance associated with the bypass path to cause insertion loss of the bypass path to be reduced.

[0007] The at least one inductor can compensation for at least one of an off state capacitance of the first switch, an off state capacitance of the second switch, or a capacitance of a transmission line of the bypass path.

[0008] The at least one inductor can include a first inductor configured to compensate for an off state capacitance of the first switch. The off state capacitance of the first switch can include an off state series capacitance and an off state shunt capacitance. The first switch can be coupled between the first inductor and the bypass path. The at least one inductor can also include a second inductor configured to compensate for an off state capacitance of the second switch. The at least one inductor can also include a third inductor configured to compensate for a capacitance of a transmission line of the bypass path.

[0009] The apparatus can also include a radio frequency signal path electrically coupled between the first switch and the second switch, in which the radio frequency signal path configured to process a radio frequency signal. The first switch can be configured to electrically connect an antenna port to the bypass path and electrically isolate the antenna port from the radio frequency signal path in a first state, and the first switch can be configured to electrically connect the antenna port to the radio frequency signal path and electrically isolate the antenna port from

the bypass path in a second state. The radio frequency signal path can be a receive path. The radio frequency signal path can be a transmit path.

[0010] The apparatus can include a diversity module. The diversity module can include at least the first switch, the second switch, and the bypass path. The diversity module can also include the at least one inductor. The apparatus can further include a plurality of antennas, in which the plurality of antennas includes a diversity antenna in communication with the first switch of the diversity module. The apparatus can further include an antenna switch module in communication with the second switch.

[0011] Another aspect of this disclosure is a radio frequency module comprising a first switch having at least two throws; a second switch having at least two throws; a radio frequency signal path electrically coupled between the first switch and the second switch, the radio frequency signal path configured to process a radio frequency signal, and the radio frequency signal path including a filter and a low noise amplifier; a bypass path electrically coupled between the first switch and the second switch, the bypass path configured as a transmission line between the first switch and the second switch; and an inductor configured to compensate for an off state capacitance of at least one throw of the first switch that is unconnected to the bypass path to cause insertion loss associated with the bypass path to be reduced.

In an embodiment, an apparatus is provided that includes a first switch having at least two throws, a second switch having at least two throws, a radio frequency signal path, a bypass path, and an inductor. The radio frequency signal path is electrically coupled between the first switch and the second switch. The radio frequency signal path is configured to process a radio frequency signal. The bypass path is electrically coupled between the first switch and the second switch. The inductor is configured to compensate for an off state capacitance of the first switch to cause insertion loss associated with the bypass path to be reduced.

[0012] The apparatus can further include a second inductor configured to compensate for an off state capacitance of the second switch to cause insertion loss associated with the bypass path to be reduced. The apparatus can further include a third inductor configured to compensate for a capacitance of the bypass path to cause insertion loss associated with the bypass path to be reduced.

[0013] The inductor can have a tunable inductance. The inductor can be configured as a shunt inductor. The first switch can be coupled between the inductor and the bypass path.

[0014] The apparatus can further include receive paths between the first switch and the second switch, in which the receive paths include the radio frequency signal path. The first switch can be configured to electrically connect an antenna port to the bypass path and electrically isolate the antenna port from the receive paths in a first state. The first switch can be configured to electrically connect the antenna port to a selected one of the receive paths and electrically isolate the bypass path from the antenna port and other receive paths of the receive paths in a second state.

[0015] Another aspect of this disclosure is an electronically-implemented method of reducing insertion loss associated with a bypass path. The method includes operating a diversity module in a bypass mode such that an input of the diversity module is coupled to an output of the diversity module by way of a bypass path that electrically connects a first switch having at least two throws with a second switch having at least two throws. The method also includes, while operating the diversity module in the bypass mode, substantially

canceling capacitance associated with a transmission line of the bypass path using an inductor coupled in series in the bypass path between the first switch and the second switch to cause insertion loss associated with the bypass mode to be reduced.

[0016] Another embodiment of this disclosure is an apparatus that includes a bypass path, a receive path, and at least one inductor. The bypass path electrically connects a first switch coupled to an antenna port with a second switch coupled to an antenna switch module, in which the first switch having at least two throws, and the second switch having at least two throws. The receive path is electrically coupled between the first switch with the second switch. The receive path includes a filter and a low noise amplifier. The at least one inductor is configured to compensate for capacitance associated with at least one of an off state of the first switch, an off state of the second switch, or a transmission line of the bypass path.

[0017] Another embodiment of this disclosure is an apparatus that includes a first switch having at least two throws, a second switch having at least two throws, a receive path electrically connecting the first switch and the second switch, a bypass path electrically connecting the first switch and the second switch, a first inductor, a second inductor, and a third inductor. The first inductor is configured to compensate for an off state capacitance of the first switch to cause insertion loss associate with the bypass path to be reduced. The second inductor is configured to compensate for a capacitance of a transmission line of the bypass path to cause the insertion loss associate with the bypass path to be reduced. The third inductor is configured to compensate for an off state capacitance of the second switch to cause the insertion loss associate with the bypass path to be reduced.

[0018] Another embodiment of this disclosure is an apparatus that includes a transmission line and at least one inductor. The transmission line electrically connects a first multi-throw switch with a second multi-throw switch. The at least one inductor is configured to compensate for a capacitance associated with the transmission line to cause insertion loss of the transmission line to be reduced.

[0019] The at least one inductor can compensate for capacitance of at least one of an off state capacitance of the first multi-throw switch, an off state capacitance of the second multi-throw switch, or a capacitance of the transmission line to cause insertion loss of the transmission line to be reduced.

[0020] Another embodiment of this disclosure is an apparatus that includes a transmission line electrically connecting a first multi-throw switch and a second multi-throw switch and at least one inductor configured to compensate for an off state capacitance of the first multi-throw switch and an off state capacitance of the second multi-throw switch.

[0021] For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the inventions have been described herein. It is to be understood that not necessarily all such advantages may be achieved in accordance with any particular embodiment of the invention. Thus, the inventions may be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Embodiments of this disclosure will now be described, by way of non-limiting example, with reference to the accompanying drawings, in which:

[0023] Figure 1 is a schematic diagram of a diversity module according to an embodiment;

[0024] Figure 2A is a schematic block diagram of a diversity module according to another embodiment;

[0025] Figure 2B is a schematic block diagram of a diversity module according to another embodiment;

[0026] Figure 2C is a schematic block diagram of a diversity module according to another embodiment;

[0027] Figure 3 is a schematic diagram of the diversity module of Figure 2A with parasitics illustrated;

[0028] Figure 4 is a schematic diagram of illustrating parasitics of a bypass path in the diversity module of Figure 2A;

[0029] Figure 5 is a graph comparing insertion loss in the diversity module of Figure 2A with a previous diversity module;

[0030] Figure 6 is a schematic block diagram of a wireless device that includes a diversity module.

WHAT IS CLAIMED IS:

1. An electronic device with bypass path loss reduction, the electronic device comprising:

a first switch having at least two throws;

a second switch having at least two throws;

a bypass path electrically connecting the first switch and the second switch;

a receive path including a low noise amplifier, the receive path and the bypass path being connected to different throws of the first switch, and the receive path and the bypass path being connected to different throws of the second switch; and

at least one inductor configured to compensate for an off state capacitance associated with at least one throw of the first switch that is unconnected to the bypass path to cause insertion loss of the bypass path to be reduced.

2. The electronic device of claim 1 wherein the at least one inductor is configured to compensate for an off state shunt capacitance of a throw of the first switch associated with the bypass path.

3. The electronic device of claim 1 wherein the first switch is coupled between the at least one inductor and the bypass path.

4. The electronic device of claim 1 further comprising a second inductor configured to compensate for an off state capacitance of a throw of the second switch that is unconnected to the bypass path.

5. The electronic device of claim 4 further comprising a third inductor coupled in series between the first switch and the second switch in the bypass path, the third inductor configured to compensate for a capacitance of a transmission line of the bypass path.

6. The electronic device of claim 1 further comprising an other inductor coupled in series between the first switch and the second switch in the bypass path, the other inductor configured to compensate for a capacitance of a transmission line of the bypass path.

7. The electronic device of claim 1 wherein the receive path includes a band pass filter coupled between the first switch and the low noise amplifier.

8. The electronic device of claim 1 wherein the first switch is configured to electrically connect an antenna port to the bypass path and electrically isolate the antenna port from the receive path in a first state, and the first switch is configured to electrically connect the antenna port to the receive path and electrically isolate the antenna port from the bypass path in a second state.

9. The electronic device of claim 1 comprising a diversity module including at least the first switch, the second switch, and the bypass path.

10. The electronic device of claim 9 further comprising a plurality of antennas, the plurality of antennas including a diversity antenna in communication with the first switch of the diversity module.

11. The electronic device of claim 10 further comprising an antenna switch module in communication with the second switch.

12. A radio frequency module comprising:

a first switch having at least two throws;

a second switch having at least two throws;

a radio frequency signal path electrically coupled between the first switch and the second switch, the radio frequency signal path configured to process a radio frequency signal, and the radio frequency signal path including a filter and a low noise amplifier;

a bypass path electrically coupled between the first switch and the second switch, the bypass path configured as a transmission line between the first switch and the second switch; and

an inductor configured to compensate for an off state capacitance of at least one throw of the first switch that is unconnected to the bypass path to cause insertion loss associated with the bypass path to be reduced.

13. The radio frequency module of claim 12 further comprising a second inductor configured to compensate for an off state capacitance of at least one throw of the second switch that is unconnected to the bypass path to cause insertion loss associated with the bypass path to be reduced.

14. The radio frequency module of claim 13 further comprising a third inductor coupled in series between the first switch and the second switch in the bypass path, the third inductor configured to compensate for a parasitic capacitance of the transmission line to cause insertion loss associated with the bypass path to be reduced.

15. The radio frequency module of claim 12 wherein the inductor has a tunable inductance.

16. The radio frequency module of claim 12 wherein the first switch includes at least three throws and the off state capacitance of the first switch is associated with more than one of the at least three throws of the first switch.

17. The radio frequency module of claim 12 comprising receive paths between the first switch and the second switch, the receive paths including the radio frequency signal path, the first switch being configured to electrically connect an antenna port to the bypass path and electrically isolate the antenna port from the receive paths in a first state, and the first switch being configured to electrically connect the antenna port to a selected one of the receive paths and electrically isolate the bypass path from the antenna port and other receive paths of the receive paths in a second state.

18. An electronically-implemented method of reducing insertion loss associated with a bypass path, the method comprising:

operating a diversity module in a bypass mode such that an input of the diversity module is coupled to an output of the diversity module by way of a bypass path that electrically connects a first switch having at least two throws with a second switch having at least two throws, the diversity module being configured to receive a radio frequency signal from a diversity antenna of a mobile device; and

while operating the diversity module in the bypass mode, substantially canceling capacitance associated with a transmission line of the bypass path using an

inductor coupled in series in the bypass path between the first switch and the second switch to cause insertion loss associated with the bypass mode to be reduced.

19. The electronically-implemented method of claim 18 further comprising substantially canceling capacitance associated with an off state of the first switch while operating the diversity module in the bypass mode.

20. The electronically-implemented method of claim 19 wherein the off state capacitance of the first switch includes an off state series capacitance associated with a throw of the first switch that is unconnected to the bypass path.

21. The radio frequency module of claim 12 wherein the inductor is electrically coupled to a series element of at least one throw of the at least two throws of the first switch in all states of the first switch.

22. The radio frequency module of claim 12 wherein the inductor has a first end electrically connected to the first switch and a second end electrically connected to ground.

23. The radio frequency module of claim 12 further comprising a second radio frequency signal path coupled between the first switch and the second switch, the second radio frequency signal path including a second filter and a second low noise amplifier, and the second filter being a bass pass filter having a different pass band than the filter.