DIVERSITY RECEIVER FRONT END SYSTEM WITH POST-AMPLIFIER FILTERS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application No. 62/073,043 filed October 31, 2014, entitled DIVERSITY RECEIVER FRONT END SYSTEM, U.S. Provisional Application No. 62/077,894, filed November 10, 2014, entitled DIVERSITY RECEIVER ARCHITECTURE HAVING PRE AND POST LNA FILTERS FOR SUPPORTING CARRIER AGGREGATION, U.S. Application No. 14/727,739, filed June 1, 2015, entitled DIVERSITY FRONT END SYSTEM WITH VARIABLE-GAIN AMPLIFIERS, and U.S. Application No. 14/735,482, filed June 10, 2015, entitled DIVERSITY RECEIVER FRONT END SYSTEM WITH POST-AMPLIFIER FILTERS, the disclosure of each of which is *hereby expressly incorporated by reference herein in its entirety.*

BACKGROUND

Field

[0002] The present disclosure generally relates to wireless communication systems having one or more diversity receiving antennas.

Description of the Related Art

[0003] In wireless communication applications, size, cost, and performance are examples of factors that can be important for a given product. For example, to increase performance, wireless components such as a diversity receive antenna and associated circuitry are becoming more popular.

[0004] In many radio-frequency (RF) applications, a diversity receive antenna is placed physically far from a primary antenna. When both antennas are used at once, a transceiver can process signals from both antennas in order to increase data throughput.

SUMMARY

[0005] In accordance with the present disclosure, there is provided a receiving system comprising:

a first multiplexer having an input for coupling to a diversity antenna, and a second multiplexer having an output for coupling to a separate receiving circuit;

a controller configured to selectively activate one or more of a plurality of paths between the input of the first multiplexer and the output of the second multiplexer;

a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and configured to amplify a signal received at the amplifier from the diversity antenna;

a plurality of pre-amplifier bandpass filters, each one of the plurality of pre-amplifier bandpass filters disposed along a corresponding path of the plurality of paths at an input of a corresponding amplifier of the plurality of amplifiers, individual pre-amplifier bandpass filters configured to filter a signal received at the pre-amplifier bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier; and

a plurality of post-amplifier bandpass filters, each one of the plurality of post-amplifier bandpass filters disposed along a corresponding path of the plurality of paths at an output of a corresponding amplifier of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band and to reduce the out-of-band noise amplified by the corresponding amplifier.

[0005A] In accordance with the present disclosure, there is also provided a radio-frequency (RF) module comprising:

a packaging substrate configured to receive a plurality of components; and

a receiving system implemented on the packaging substrate, the receiving system including a first multiplexer having an input for coupling to a diversity antenna, and a second multiplexer having an output for coupling to a separate receiving circuit; a controller configured to selectively activate one or more of a plurality of paths between the input of the first

multiplexer and the output of a second multiplexer; a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and configured to amplify a signal received at the amplifier from the diversity antenna; and a first plurality of bandpass filters, each one of the first plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an output of a corresponding one of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band, and a second plurality of bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier and that is reduced by a corresponding bandpass filter of the first plurality of bandpass filters.

[0005B] In accordance with the present disclosure, there is further provided a wireless device comprising:

a diversity antenna configured to receive a signal;

a diversity receiver module in communication with the diversity antenna, and including a receiving system, the receiving system including a first multiplexer having an input coupled to the diversity antenna, and a second multiplexer having an output; a controller configured to selectively activate one or more of a plurality of paths between the input of the first multiplexer and the output of the second multiplexer; a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and configured to amplify the signal; and a first plurality of bandpass filters, each one of the first plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an output of a corresponding one of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band, and a second plurality of bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding

one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier and that is reduced by a corresponding bandpass filter of the first plurality of bandpass filters;

a separate receiver circuit external to the diversity receiver module and coupled to the output of the second multiplexer through a transmission line; and

a transceiver coupled to the separate receiver circuit, and configured to further process a signal processed by the diversity receiver module and the separate receiver circuit.

[0005C] In some implementations, the present disclosure relates to a receiving system including a controller configured to selectively activate one or more of a plurality of paths between an input of a first

CLAIMS

1. A receiving system comprising:

a first multiplexer having an input for coupling to a diversity antenna, and a second multiplexer having an output for coupling to a separate receiving circuit;

a controller configured to selectively activate one or more of a plurality of paths between the input of the first multiplexer and the output of the second multiplexer;

a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and configured to amplify a signal received at the amplifier from the diversity antenna;

a plurality of pre-amplifier bandpass filters, each one of the plurality of pre-amplifier bandpass filters disposed along a corresponding path of the plurality of paths at an input of a corresponding amplifier of the plurality of amplifiers, individual pre-amplifier bandpass filters configured to filter a signal received at the pre-amplifier bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier; and

a plurality of post-amplifier bandpass filters, each one of the plurality of post-amplifier bandpass filters disposed along a corresponding path of the plurality of paths at an output of a corresponding amplifier of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band and to reduce the out-of-band noise amplified by the corresponding amplifier.

2. The system of claim 1 wherein one of the plurality of post-amplifier bandpass filters disposed along a first path and one of the plurality of pre-amplifier bandpass filters disposed along the first path are complementary.

3. The system of claim 2 wherein one of the pre-amplifier bandpass filters or one of the post-amplifier bandpass filters disposed along the first path attenuates frequencies below a first frequency band more than frequencies above the first frequency band and another of the pre-amplifier bandpass filters or another of the post-amplifier bandpass filters disposed along the first path attenuates frequencies above the first frequency band more than frequencies below the first frequency band.

4. The system of claim 1 further comprising a transmission line coupled to the output of the second multiplexer and coupled to the separate receiving circuit including a multiplexer.

5. The system of claim 4 wherein the separate receiving circuit does not include a bandpass filter.

6. The system of claim 5 wherein the multiplexer of the separate receiving circuit includes a sample switch.

7. The system of claim 4 wherein the separate receiving circuit includes one or more amplifiers.

8. The system of claim 7 wherein a number of the one or more amplifiers of the separate receiving circuit is less than a number of the plurality of amplifiers.

9. The system of claim 1 wherein at least one of the plurality of amplifiers includes a low-noise amplifier.

10. The system of claim 1 wherein at least one of the plurality of amplifiers includes a variable-gain amplifier.

11. The system of claim 1 further comprising one or more tunable matching circuits disposed at one or more of the input of the first multiplexer and the output of the second multiplexer.

12. The system of claim 1 wherein the controller is configured to selectively activate the one or more of the plurality of paths based on a band select signal received by the controller.

13. The system of claim 1 wherein the controller is configured to selectively activate the one or more of the plurality of paths by transmitting a splitter control signal to the first multiplexer and a combiner control signal to the second multiplexer.

14. A radio-frequency (RF) module comprising:

a packaging substrate configured to receive a plurality of components; and

a receiving system implemented on the packaging substrate, the receiving system including a first multiplexer having an input for coupling to a diversity antenna, and a second multiplexer having an output for coupling to a separate receiving circuit; a controller configured to selectively activate one or more of a plurality of paths between the input of the first multiplexer and the output of the second multiplexer; a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and

configured to amplify a signal received at the amplifier from the diversity antenna; and a first plurality of bandpass filters, each one of the first plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an output of a corresponding one of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band, and a second plurality of bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier and that is reduced by a corresponding bandpass filter of the first plurality of bandpass filters.

15. The RF module of claim 14 wherein the RF module is a diversity receiver module, and the separate receiving circuit is implemented external to the diversity receive module.

16. The RF module of claim 14 wherein the receiving system further includes a second plurality of bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter from the diversity antenna to a respective frequency band.

17. The RF module of claim 14 wherein the plurality of paths includes an off-module path including an off-module bandpass filter and one of the plurality of amplifiers.

18. A wireless device comprising:

a diversity antenna configured to receive a signal;

a diversity receiver module in communication with the diversity antenna and including a receiving system, the receiving system including a first multiplexer having an input coupled to the diversity antenna, and a second multiplexer having an output; a controller configured to selectively activate one or more of a plurality of paths between the input of the first multiplexer and the output of the second multiplexer; a plurality of amplifiers, each one of the plurality of amplifiers disposed along a corresponding one of the plurality of paths and configured to amplify the signal; a first plurality of bandpass filters, each one of the first plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an output of a corresponding one of the plurality of amplifiers and configured to filter the signal amplified by the corresponding amplifier to a respective frequency band, and a second plurality of

bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter to a respective frequency band resulting in out-of-band noise that is amplified by the corresponding amplifier and that is reduced by a corresponding bandpass filter of the first plurality of bandpass filters;

a separate receiver circuit external to the diversity receiver module and coupled to the output of the second multiplexer through a transmission line; and

a transceiver coupled to the separate receiver circuit, and configured to further process a signal processed by the diversity receiver module and the separate receiver circuit.

19. The wireless device of claim 18 further comprising a primary antenna and a front-end module in communication with the primary antenna, the transceiver being configured to process a signal associated with the front-end module and the primary antenna.

20. The wireless device of claim 18 wherein the receiving system further includes a second plurality of bandpass filters, each one of the second plurality of bandpass filters disposed along a corresponding one of the plurality of paths at an input of a corresponding one of the plurality of amplifiers and configured to filter a signal received at the bandpass filter from the diversity antenna to a respective frequency band.

21. The system of claim 2 wherein an individual pre-amplifier bandpass filter disposed along the first path phase shifts signals through a first phase shift and an individual post-amplifier bandpass filter disposed along the first path phase shifts the signals through a second phase shift that is opposite to the first phase shift.

22. The RF module of claim 14 wherein one of the bandpass filters disposed along the first path attenuates frequencies below a first frequency band more than frequencies above the first frequency band and another of the bandpass filters disposed along the first path attenuates frequencies above the first frequency band more than frequencies below the first frequency band.

23. The wireless device of claim 18 wherein one of the bandpass filters disposed along the first path attenuates frequencies below a first frequency band more than frequencies above the first frequency band and another of the bandpass filters disposed along the first path attenuates frequencies above the first frequency band more than frequencies below the first frequency band.