CIRCUITS AND METHODS RELATED TO SWITCHLESS CARRIER AGGREGATION IN RADIO-FREQUENCY RECEIVERS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application No. 61/978,810 filed April 11, 2014, entitled CIRCUITS AND METHODS RELATED TO SWITCHLESS CARRIER AGGREGATION IN RADIO-FREQUENCY RECEIVERS, the disclosure of which is hereby expressly incorporated by reference herein in its entirety.

BACKGROUND

Field

[0002] The present disclosure relates to carrier aggregation in radio-frequency (RF) receivers.

Description of the Related Art

[0003] In some RF applications, cellular carrier aggregation (CA) can involve two or more RF signals being processed through a common path. For example, carrier aggregation can involve use of a path for a plurality of bands having frequency ranges that are sufficiently separated. In such a configuration, simultaneous operation of more than one band can be achieved.

SUMMARY

[0004] According to a first aspect of the present disclosure, there is provided a carrier aggregation (CA) circuit comprising an input node, a common node, and an output node; a first filter configured to allow operation in a first frequency band; a second filter configured to allow operation in a second frequency band; a first amplification path implemented between the input node and the output node, and including the first filter, a first current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches; and a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and second current converter stages and the common adder stage being parts of a low-noise amplifier.

[0005] In some embodiments, the first signal path and the second signal path can be parts of a low-noise amplifier (LNA). The first signal path and the second signal path being substantially free of switches can allow the CA circuit to operate with a reduced noise figure.

[0006] In some embodiments, the plurality of amplification stages of each of the first signal path and the second signal path can include a first stage and a second stage. The first stage can be configured to convert the respective RF signal into current. The second stage can be configured to add the current.

[0007] In some embodiments, the first stage of each of the first signal path and the second signal path can include a first bipolar junction transistor (BJT) configured to receive the respective RF signal through its base and yield an output through its collector. The CA circuit can further include a bias circuit coupled to the first BJT. The bias circuit can include a switchable bias

supply path between a bias node and the base, with the switchable bias supply path configured to be capable of being turned on or off to activate or deactivate the respective first BJT. The bias circuit can further include a switchable shunt path configured to provide a shunt path when the respective first BJT is deactivated.

[0008] In some embodiments, the first BJT of each of the first signal path and the second signal path can include an emitter coupled to ground through an inductance. The emitters of the first BJT of the first signal path and the second signal path can be coupled to ground through separate inductances, or through a common inductance.

[0009] In some embodiments, the second stages of the first signal path and the second signal path can be provided by a shared second BJT configured to receive the RF signals from the first BJTs through its emitter and yield an output through its collector. The shared second BJT can be configured to receive a cascode bias voltage Vcas through its base. The cascode bias voltage Vcas can be adjustable depending on the number of inputs into the shared second BJT.

[0010] In some embodiments, the second stage of each of the first signal path and the second signal path can include a separate second BJT configured to receive the RF signal from the respective first BJT through its

emitter and yield an output through its collector. Each separate second BJT can be configured to receive its respective cascode bias voltage Vcas through its base.

[0011] In some embodiments, the first filter and the second filter can be parts of a diplexer. The diplexer can include an input port configured to receive an RF signal from an antenna.

[0012] In some embodiments, each of the first signal path and the second signal path can be capable of being in an active state or an inactive state to allow the CA circuit to operate in a CA mode or a non-CA mode without separate switches along the first signal path and the second signal path. The active state or the inactive state for each of the first signal path and the second signal path can be achieved by activating or deactivating the respective first stage.

[0013] According to a second aspect of the present disclosure, there is provided a radio-frequency module comprising a packaging substrate configured to receive a plurality of components; and a carrier aggregation circuit implemented on the packaging substrate, and including an input node, a common node, and an output node, the carrier aggregation circuit further including a first filter configured to allow operation in a first frequency band and a second filter configured to allow operation in a second frequency band, the carrier aggregation circuit further including a first amplification path implemented between the input node and the output node, and including the first filter, a first current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches, the carrier aggregation circuit further including a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and

second current converter stages and the common adder stage being parts of a low-noise amplifier.

[0014] In some embodiments, each of the first filter and the second filter can include a surface acoustic wave (SAW) filter. The first SAW filter and the second SAW filter can be implemented as a diplexer. The plurality of amplification stages for each of the first signal path and the second signal path can be part of a low-noise amplifier (LNA).

[0015] In some embodiments, the RF module can be a front-end module. In some embodiments, the RF module can be a diversity receive (DRx) module.

[0016] In some teachings, the present disclosure relates to a method for fabricating a radio-frequency (RF) module. The method includes providing or forming a packaging substrate configured to receive a plurality of components, and implementing a carrier aggregation (CA) circuit on the packaging substrate. The CA circuit includes a first filter configured to allow operation in a first frequency band and a second filter configured to allow operation in a second frequency band. The CA circuit further includes a first signal path implemented between the first filter and an output node, with the first signal path including a plurality of amplification stages configured to amplify a first radio-frequency (RF) signal, and the first signal path being substantially free of switches. The CA circuit further includes a second signal path implemented between the second filter and the output node, with the second signal path including a plurality of amplification stages configured to amplify a second RF signal, and the second signal path being substantially free of switches.

[0017] According to yet another aspect of the present disclosure, there is provided a wireless device comprising a receiver configured to process radio-frequency signals; module in communication with the receiver, and including a carrier aggregation circuit configured to route the radio-frequency signals, the carrier aggregation circuit including an input node, a common node, and an output node; a first filter configured to allow operation in a first frequency band and a second filter configured to allow operation in a second frequency band; a first amplification path implemented between the input node and the output node, and including the first filter, a first current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches; and a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free

of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and second current converter stages and the common adder stage being parts of a low-noise amplifier; and an antenna in communication with the radio-frequency module, and configured to receive the radio-frequency signals.

[0018] In some embodiments, the RF device can be a wireless device. Such a wireless device can be, for example, a cellular phone. In some

WHAT IS CLAIMED IS:

1. A carrier aggregation (CA) circuit comprising

an input node, a common node, and an output node;

a first filter configured to allow operation in a first frequency band;

a second filter configured to allow operation in a second frequency band;

a first amplification path implemented between the input node and the output node, and including the first filter, a first current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches; and

a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and second current converter stages and the common adder stage being parts of a low-noise amplifier.

2. The carrier aggregation circuit of claim 1 wherein the first amplification path and the second amplification path being free of switches allows the carrier aggregation circuit to operate with a reduced noise figure.

3. The carrier aggregation circuit of claim 1 further comprising a bias circuit coupled to the bipolar junction transistors of the first and second current converter stages, and including a switchable bias supply path between a respective bias node and the respective base, the switchable bias supply path

configured to be capable of being turned on or off to activate or deactivate the respective bipolar junction transistor.

4. The carrier aggregation circuit of claim 3 wherein the bias circuit further includes a switchable shunt path configured to provide a shunt path when the respective bipolar junction transistor is deactivated.

5. The carrier aggregation circuit of claim 1 wherein the bipolar junction transistor of each of the first and second current converter stages includes an emitter coupled to ground through an inductance.

6. The carrier aggregation circuit of claim 1 wherein the shared bipolar junction transistor is configured to receive a cascode bias voltage through its base.

7. The carrier aggregation circuit of claim 1 wherein each of the first amplification path and the second amplification path is capable of being in an active state or an inactive state to allow the carrier aggregation circuit to operate in a carrier aggregation mode or a non-carrier aggregation mode without separate switches along the first amplification path and the second amplification path.

8. The carrier aggregation circuit of claim 7 wherein the active state or the inactive state for each of the first amplification path and the second amplification path is achieved by activating or deactivating the respective current converter stage.

9. A radio-frequency module comprising:

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

a carrier aggregation circuit implemented on the packaging substrate, and including an input node, a common node, and an output node, the carrier aggregation circuit further including a first filter configured to allow operation in a first frequency band and a second filter configured

to allow operation in a second frequency band, the carrier aggregation circuit further including a first amplification path implemented between the input node and the output node, and including the first filter, a first current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches, the carrier aggregation circuit further including a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and second current converter stages and the common adder stage being parts of a low-noise amplifier.

10. The radio-frequency module of claim 9 wherein each of the first filter and the second filter includes a surface acoustic wave filter.

11. The radio-frequency module of claim 10 wherein the radio-frequency module is a diversity receive module.

12. A wireless device comprising:

a receiver configured to process radio-frequency signals;

module in communication with the receiver, and including a carrier aggregation circuit configured to route the radio-frequency signals, the carrier aggregation circuit including an input node, a common node, and an output node; a first filter configured to allow operation in a first frequency band and a second filter configured to allow operation in a second frequency band; a first amplification path implemented between the input node and the output node, and including the first filter, a first

current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and a common adder stage implemented as a shared bipolar junction transistor, the first amplification path free of switches; and a second amplification path implemented between the input node and the output node, and including the second filter, a second current converter stage implemented as a bipolar junction transistor configured to receive a signal through its base and generate an output through its collector, the common node, and the common adder stage, the second amplification path free of switches, the shared bipolar junction transistor configured to receive the signals output from the bipolar junction transistors of the first and second current converter stages through its emitter and generate an output through its collector, the first and second current converter stages and the common adder stage being parts of a low-noise amplifier; and

an antenna in communication with the radio-frequency module, and configured to receive the radio-frequency signals.

13. The wireless device of claim 12 wherein the antenna includes a diversity antenna, and the module includes a diversity receive module.

14. The wireless device of claim 13 further comprising an antenna switch module configured to route the radio-frequency signals from the diversity antenna to the receiver, such that the diversity receive module is implemented between the diversity antenna and the antenna switch module.