

DOMINO CIRCUIT AND RELATED ARCHITECTURES AND METHODS FOR CARRIER AGGREGATION

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims priority to U.S. Provisional Application No. 62/044,169 filed August 29, 2014, entitled CIRCUITS AND METHODS RELATED TO CARRIER AGGREGATION, 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) applications.

Description of the Related Art

[0003] In some radio-frequency (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] In some implementations, the present disclosure relates to a radio-frequency (RF) circuit that includes a first signal path and a second signal path, with the first signal path being associated with a first frequency band, and the second signal path being associated with a second frequency band. The first signal path is configured to present an approximately zero impedance to a signal in the second frequency band, and the second signal path is configured to present an approximately zero impedance to a signal in the first frequency band. The signal in the second frequency band is different from the signal in the first frequency band. The RF circuit further includes a coupling circuit that couples the first and second signal paths. The coupling circuit is configured such that the

approximately zero impedance presented by the first signal path to the signal in the second frequency band results in the signal in the second frequency band being substantially excluded from the first signal path, and such that the approximately zero impedance presented by the second signal path to the signal in the first frequency band results in the signal in the first frequency band being substantially excluded from the second signal path.

[0004a] An aspect relates to a radio frequency (RF) module that comprises a packaging substrate configured to receive a plurality of components; and an RF circuit implemented on the packaging substrate, the RF circuit including a first signal path and a second signal path, the first signal path associated with a first frequency band, the second signal path associated with a second frequency band, the first signal path configured to present an approximately zero impedance to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance to a signal in the first frequency band, the signal in the second frequency band being different from the signal in the first frequency band, the RF circuit further including a coupling circuit that couples the first and second signal paths, the coupling circuit configured such that the approximately zero impedance presented by the first signal path to the signal in the second frequency band results in the signal in the second frequency band being substantially excluded from the first signal path, and such that the approximately zero impedance presented by the second signal path to the signal in the first frequency band results in the signal in the first frequency band being substantially excluded from the second signal path.

[0005] In some embodiments, each of the first and second signal paths can be further configured to present a matched impedance for a signal in the corresponding frequency band. The coupling circuit can be further configured such that the matched impedance of each signal path results in the corresponding signal to be included in the signal path.

[0006] In some embodiments, the RF circuit can be configured for carrier-aggregation (CA) of a received signal having portions in both of the first and second frequency bands. The coupling circuit can further include a common input node for the received signal. Each of the first and second signal paths can

include a filter and a transmission line between a corresponding node of the coupling circuit and the filter. The filter can include a band-pass filter such as a surface acoustic wave (SAW) filter.

[0007] In some embodiments, the coupling circuit can include a first LC circuit and a second LC circuit that couple the common input node to ground in a parallel manner. The first LC circuit can include a first inductance L1 and a first capacitance C1 in series, and the second LC circuit can include a second capacitance C2 and a second inductance in series. An input of the first signal path can be at a node between L1 and C1, and an input of the second signal path can be at a node between C2 and L2.

[0008] In some embodiments, the RF circuit can further include a first grounding switch between the input of the first signal path and ground, and a second grounding switch between the input of the second signal path and ground. The first and second grounding switches can be configured to allow non-CA modes of operation. Each of the first and second grounding switches can be open for a CA mode of operation. The first grounding switch can be open and the second grounding switch can be closed for a non-CA operation in the first frequency band, and the second grounding switch can be open and the first

grounding switch can be closed for a non-CA operation in the second frequency band.

[0009] In some embodiments, the matched impedance can have a value of approximately 50 Ohms. The first frequency band can include, for example, band B2, and the second frequency band include, for example, band B4. The first frequency band can further include, for example, band B25.

[0010] ~~According to some implementations, the present disclosure~~An aspect relates to a radio-frequency (RF) circuit assembly that includes a common node associated with an aggregated signal including at least one first signal in a first frequency band and at least one second signal in a second frequency band. The RF circuit assembly further includes a first signal path and a second signal path, with the first signal path being associated with the first frequency band, the second signal path being associated with the second frequency band. The first signal path is configured to present an approximately zero impedance to the second signal, and the second signal path is configured to present an approximately zero impedance to the first signal. The RF circuit assembly further includes a coupling circuit that couples the first and second signal paths to the common node. The coupling circuit is configured such that the approximately zero impedance presented by the first signal path to the second signal results in the second signal being excluded from the first signal path, and the approximately zero impedance presented by the second signal path to the first signal results in the first signal being excluded from the second signal path.

[0011] ~~In accordance with some implementations, the present disclosure~~An aspect relates to a radio-frequency (RF) circuit assembly that includes a first node associated with a first signal in a first frequency band and a second node associated with a second signal in a second frequency band. The RF circuit assembly further includes a first signal path coupled to the first node and associated with the first frequency band, and a second signal path coupled to the second node and associated with the second frequency band. The first signal path is configured to present an approximately zero impedance to the second signal, and the second signal path is configured to present an approximately zero impedance to the first signal. The RF circuit assembly further includes a coupling circuit that couples the first and second signal paths to a

common node. The coupling circuit is configured such that the approximately zero impedance

presented by the first signal path to the second signal results in the second signal being excluded from the first signal path and thereby directed to the common node, and the approximately zero impedance presented by the second signal path to the first signal results in the first signal being excluded from the second signal path and thereby directed to the common node.

[0012] ~~In a number of teachings, the present disclosure~~An aspect relates to a method for processing radio-frequency (RF) signals. The method includes providing a first signal path and a second signal path, with the first signal path being associated with a first frequency band, and the second signal path being associated with a second frequency band. The method further includes presenting, at the first signal path, an approximately zero impedance to a signal in the second frequency band, and presenting, at the second signal path, an approximately zero impedance to a signal in the first frequency band. The signal in the second frequency band is different from the signal in the first frequency band. The method further includes coupling the first and second signal paths such that the approximately zero impedance presented by the first signal path to the signal in the second frequency band results in the signal in the second frequency band being substantially excluded from the first signal path, and such that the approximately zero impedance presented by the second signal path to the signal in the first frequency band results in the signal in the first frequency band being substantially excluded from the second signal path.

[0013] In a number of implementations, the present disclosure relates to a radio-frequency (RF) module that includes a packaging substrate configured to receive a plurality of components, and an RF circuit implemented on the packaging substrate. The RF circuit includes a first signal path and a second signal path, with the first signal path being associated with a first frequency band, and the second signal path being associated with a second frequency band. The first signal path is configured to present an approximately zero impedance to a signal in the second frequency band, and the second signal path is configured to present an approximately zero impedance to a signal in the first frequency band. The signal in the second frequency band is different from the signal in the first frequency band. The RF circuit further includes a coupling circuit that couples the first and second signal paths. The coupling circuit is configured such that the approximately zero impedance presented by the first signal path to the signal in

the second frequency band results in the signal in the second frequency band being substantially excluded from the first signal path, and such that the approximately zero impedance presented by the second signal path to the signal in the first frequency band results in the signal in the first frequency band being substantially excluded from the second signal path.

[0014] In some embodiments, each of the first and second signal paths can include a filter and a transmission line between a corresponding node of the coupling circuit and the filter. The first and second filters can be configured to yield a diplexed output. The RF circuit can further include a low-noise amplifier (LNA) configured to operate in the first and second frequency bands, and have an input configured to receive the diplexed output of the first and second filters.

[0015] According to ~~some teachings~~an aspect, the present disclosure relates to a wireless device that includes an antenna and a front-end module (FEM) in communication with the antenna. The FEM includes an RF circuit having a first signal path and a second signal path, with the first signal path being associated with a first frequency band, and the second signal path being associated with a second frequency band. The first signal path is configured to present an approximately zero impedance to a signal in the second frequency band, and the second signal path is configured to present an approximately zero impedance to a signal in the first frequency band. The signal in the second frequency band is different from the signal in the first frequency band. The RF circuit further includes a coupling circuit that couples the first and second signal paths. The coupling circuit is configured such that the approximately zero impedance presented by the first signal path to the signal in the second frequency band results in the signal in the second frequency band being substantially excluded from the first signal path, and such that the approximately zero impedance presented by the second signal path to the signal in the first frequency band results in the signal in the first frequency band being substantially excluded from the second signal path. The wireless device further includes a receiver in communication with the FEM and configured to process the signals in the first and second frequency bands.

[0016] ~~In some implementations, the present disclosure~~An aspect relates to a radio-frequency (RF) circuit that includes a first signal path configured to present an approximately zero impedance at an input for a signal out of a first frequency

open for a CA mode of operation. The first grounding switch can be open and the second grounding switch can be closed for a non-CA operation in the first frequency band, and the second grounding switch can be open and the first grounding switch can be closed for a non-CA operation in the second frequency band.

[0021] In some embodiments, the matched impedance can have a value of approximately 50 Ohms. The first frequency band can include, for example, band B2, and the second frequency band can include, for example, band B4. The first frequency band can further include, for example, band B25.

[0022] According to ~~some implementations~~ an aspect, the present disclosure relates to a method for routing radio-frequency (RF) signals. The method includes presenting a band-dependent impedance at an input of a first signal path for a first frequency band and at an input of a second signal path for a second frequency band. The band-dependent impedance includes an approximately zero impedance for an out-of-band signal for each of the first and second frequency bands. The method further includes receiving an RF signal having the out-of-band signal for each of the first and second frequency bands. The method further includes excluding the out-of-band signal from each of the first and second signal paths based on the approximately zero impedance presented by the corresponding signal path.

[0023] In some embodiments, the band-dependent impedance can further include a matched impedance for an in-band signal for each of the first and second frequency bands. The method can further include allowing the in-band signal to pass to each of the first and second signal paths based on the matched impedance presented by the corresponding signal path.

[0024] In accordance with ~~some teachings~~ an aspect, the present disclosure relates to a carrier-aggregation (CA) system configured to exclude an out-of-band signal in each of a plurality of signal paths by an out-of-band impedance of approximately zero presented by the signal path.

[0025] In some embodiments, the CA system can be further configured to include an in-band signal in each of the plurality of signal paths by a matched in-band impedance presented by the signal path. The out-of-band impedance of approximately zero can be obtained by a net impedance adjustment based on a tendency of impedance change associated with a transmission property of the

signal path. Each of the plurality of signal paths can include a band-pass filter. The tendency of impedance change can include a change towards a zero impedance from an impedance presented by the filter. The net impedance adjustment can yield an impedance of approximately zero for the signal path for the out-of-band signal. The approximately zero impedance of the signal path for the out-of-band signal can be obtained at least in part by a selected length of a transmission line associated with the filter.

[0026] ~~In a number of implementations, the present disclosure~~An aspect relates to a radio-frequency (RF) module that includes a packaging substrate configured to receive a plurality of components, and an RF circuit implemented on the packaging substrate. The RF circuit includes a first signal path configured to present an approximately zero impedance at an input for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at an input for a signal out of a second frequency band. The RF circuit further includes a coupling circuit that couples the inputs of the first and second signal paths. The coupling circuit is configured such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

[0027] In some embodiments, each of the first and second signal paths can include a filter and a transmission line between the corresponding input and the filter. The first and second filters can be configured to yield a diplexed output. The RF circuit can further include a low-noise amplifier (LNA) configured to operate in the first and second frequency bands, with the LNA having an input configured to receive the diplexed output of the first and second filters.

[0028] ~~In some implementations, the present disclosure~~An aspect 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 an RF circuit on the packaging substrate. The RF circuit includes a first signal path configured to present an approximately zero impedance at an input for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at an input for a signal out of a second frequency band. The RF circuit further includes a coupling circuit that couples the inputs of the first and second signal paths. The coupling circuit is configured such that the approximately zero impedance of each

signal path results in the corresponding signal to be substantially excluded from the signal path.

[0029] In ~~some implementations~~an aspect, the present disclosure relates to a wireless device that includes a receiver configured to process RF signals, and a front-end module (FEM) in communication with the receiver. The FEM includes a carrier aggregation (CA) system having a first signal path configured to present an approximately zero impedance at an input for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at an input for a signal out of a second frequency band. The RF circuit further includes a coupling circuit that couples the inputs of the first and second signal paths. The coupling circuit is configured such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

[0030] 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 invention 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

[0031] Figure 1 shows a signal routing configuration where a coupling circuit can couple a common signal node to a first signal processing component and a second signal processing component.

[0032] Figure 2 shows a more specific example of the signal routing configuration of Figure 1.

[0033] Figure 3 shows a carrier-aggregation (CA) circuit that can be implemented as a more specific example of a CA circuit of Figure 2.

[0034] Figure 4 shows an example of input switches that can be implemented for duplexed operation of two band-pass filters.

[0035] Figure 5 shows typical responses of the band-pass filters of the example of Figure 4.