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] An aspect relates to a radio-frequency (RF) circuit that includes a first signal path having a first node and a second signal path having a second node, 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 at the first node to a signal in the second frequency band, and the second signal path is configured to present an approximately zero impedance at the second node 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 including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the

in the signal in the second frequency band being is excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.

[0004a] An aspect relates to a radio-frequency (RF) module comprising: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 having a first node and a second signal path having a second node, 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 at the first node to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance at the second node 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 including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.[0004b] An aspect relates to a wireless device comprising: an antenna; a front-end module in communication with the antenna, and including an RF circuit having a first signal path with a first node and a second signal path with a second node, 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 at the first node to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance at the second node 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 including a first

inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected 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 is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path; and a receiver in communication with the front-end module and configured to process the signals in the first and second frequency bands.[0004c] An aspect relates to a method for processing radio-frequency (RF) signals, the method comprising: providing a first signal path having a first node and a second signal path having a second node, the first signal path associated with a first frequency band, the second signal path associated with a second frequency band; presenting, at the first node, an approximately zero impedance to a signal in the second frequency band; presenting, at the second node, 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; and coupling the first and second signal paths with a common node, such that a first inductance L1 couples the common node and the first node, a first capacitance C1 couples the first node and a ground, a second capacitance C2 couples the common node and the second node, and a second inductance L2 couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.

[0004d] An aspect relates to a radio-frequency (RF) circuit assembly comprising: 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; a first signal path having a first node and a second signal path having a second node, the first signal path associated with the first frequency band, the second signal path associated with the second frequency band, the first signal path configured to present an approximately zero impedance at the first

node to the second signal, and the second signal path configured to present an approximately zero impedance at the second node to the first signal; and a coupling circuit that couples the first and second signal paths to the common node, the coupling circuit including a first inductance L1 that couples the common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the second signal is excluded from the first signal path, and the first signal is excluded from the second signal path.

[0004e] An aspect relates to a radio-frequency (RF) circuit assembly comprising: 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; 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 configured to present an approximately zero impedance at the first node to the second signal, and the second signal path configured to present an approximately zero impedance at the second node to the first signal; a coupling circuit that couples the first and second signal paths to a common node, the coupling circuit including a first inductance L1 that couples the common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the second signal is excluded from the first signal path and thereby directed to the common node, and the first signal is excluded from the second signal path and thereby directed to the common node.

[0004f] An aspect relates to a radio-frequency (RF) circuit comprising: a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band; a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band; and a coupling circuit that couples the inputs of the first

and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

[0004g] A method for routing radio-frequency (RF) signals, the method comprising: presenting a band-dependent impedance at a first node of a first signal path for a first frequency band and at second node of a second signal path for a second frequency band, the band-dependent impedance including an approximately zero impedance for an out-of-band signal for each of the first and second frequency bands;receiving an RF signal having the out-of-band signal for each of the first and second frequency bands; and excluding the out-of-band signal from each of the first and second signal paths with a coupling circuit, based on the approximately zero impedance presented by the corresponding signal path, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground.

[0004h] An aspect relates to a radio-frequency (RF) module comprising: 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 configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a

second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

[0004i] An aspect relates to a method for fabricating a radio-frequency (RF) module, the method comprising: 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 including a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

[0004j] A wireless device comprising: a receiver configured to process RF signals; a front-end module in communication with the receiver, and including a carrier-aggregation system, the carrier-aggregation system including a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the 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

WHAT IS CLAIMED IS:

1. A radio-frequency (RF) circuit comprising:

a first signal path having a first node and a second signal path having a second node, 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 at the first node to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance at the second node 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; and

a coupling circuit that couples the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.

2. The RF circuit of claim 1 wherein each of the first and second signal paths is further configured to present a matched impedance for a signal in the corresponding frequency band.

3. The RF circuit of claim 2 wherein the coupling circuit is further configured such that the matched impedance of each signal path results in the corresponding signal to be included in the signal path.

4. The RF circuit of claim 3 wherein the RF circuit is configured for carrier-aggregation of a received signal having portions in both of the first and second frequency bands.

5. The RF circuit of claim 4 wherein the common node is a common input node for the received signal.

6. The RF circuit of claim 5 wherein each of the first and second signal paths includes a filter and a transmission line between the corresponding node and the filter.

7. The RF circuit of claim 6 wherein the filter includes a band-pass filter.

8. The RF circuit of claim 7 wherein the band-pass filter includes a surface acoustic wave (SAW) filter.

9. The RF circuit of claim 5 wherein an input of the first signal path is at the first node, and an input of the second signal path is the second node.

10. The RF circuit of claim 1 further comprising a first grounding switch between the first node of the first signal path and ground, and a second grounding switch between the second node of the second signal path and ground, the first and second grounding switches configured to allow a carrier-aggregation mode of operation or non-carrier-aggregation modes of operation.

11. The RF circuit of claim 10 wherein each of the first and second grounding switches is open for the carrier-aggregation mode of operation.

12. The RF circuit of claim 11 wherein the first grounding switch is open and the second grounding switch is closed for a non-carrier-aggregation operation in the first

frequency band, and the second grounding switch is open and the first grounding switch is closed for a non-carrier-aggregation operation in the second frequency band.

13. The RF circuit of claim 12 wherein the matched impedance has a value of approximately 50 Ohms.

14. The RF circuit of claim 12 wherein the first frequency band includes band B2 and the second frequency band includes band B4.

15. The RF circuit of claim 14 wherein the first frequency band further includes band B25.

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

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 having a first node and a second signal path having a second node, 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 at the first node to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance at the second node 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 including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.

17. The RF module of claim 16 wherein each of the first and second signal paths includes a filter and a transmission line between the corresponding node and the filter.

18. The RF module of claim 17 wherein the first and second filters are configured to provide a diplexed output.

19. The RF module of claim 19 wherein the RF circuit further includes a low-noise amplifier configured to operate in the first and second frequency bands, the low-noise amplifier having an input configured to receive the diplexed output of the first and second filters.

20. A wireless device comprising:

an antenna;

a front-end module in communication with the antenna, and including an RF circuit having a first signal path with a first node and a second signal path with a second node, 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 at the first node to a signal in the second frequency band, and the second signal path configured to present an approximately zero impedance at the second node 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 including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path; and

a receiver in communication with the front-end module and configured to process the signals in the first and second frequency bands.

21. A method for processing radio-frequency (RF) signals, the method comprising:

providing a first signal path having a first node and a second signal path having a second node, the first signal path associated with a first frequency band, the second signal path associated with a second frequency band;

presenting, at the first node, an approximately zero impedance to a signal in the second frequency band;

presenting, at the second node, 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; and

coupling the first and second signal paths with a common node, such that a first inductance L1 couples the common node and the first node, a first capacitance C1 couples the first node and a ground, a second capacitance C2 couples the common node and the second node, and a second inductance L2 couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the signal in the second frequency band is substantially excluded from the first signal path, and the signal in the first frequency band is substantially excluded from the second signal path.

22. A radio-frequency (RF) circuit assembly comprising:

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;

a first signal path having a first node and a second signal path having a second node, the first signal path associated with the first frequency band, the second signal path associated with the second frequency band, the first signal path configured to present an approximately zero impedance at the first node to the second signal, and the second signal path configured to present an approximately zero impedance at the second node to the first signal; and

a coupling circuit that couples the first and second signal paths to the common node, the coupling circuit including a first inductance L1 that couples the common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the second signal is excluded from the first

signal path, and the first signal is excluded from the second signal path.

23. A radio-frequency (RF) circuit assembly comprising:

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;

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 configured to present an approximately zero impedance at the first node to the second signal, and the second signal path configured to present an approximately zero impedance at the second node to the first signal;

a coupling circuit that couples the first and second signal paths to a common node, the coupling circuit including a first inductance L1 that couples the common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the second signal is excluded from the first signal path and thereby directed to the common node, and the first signal is excluded from the second signal path and thereby directed to the common node.

24. A radio-frequency (RF) circuit comprising:

a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band;

a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band; and

a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

25. The RF circuit of claim 24 wherein each of the first and second signal paths is further configured to present a matched impedance for a signal in the corresponding frequency band.

26. The RF circuit of claim 25 wherein the coupling circuit is further configured such that the matched impedance of each signal path results in the corresponding signal to be substantially included in the signal path.

27. The RF circuit of claim 26 wherein the signal out of the first frequency band is in the second frequency band, and the signal out of the second frequency band is in the first frequency band.

28. The RF circuit of claim 27 wherein the RF circuit is configured for carrier-aggregation of a received signal having portions in both of the first and second frequency bands.

29. The RF circuit of claim 28 wherein the common node is a common input node for the received signal.

30. The RF circuit of claim 29 wherein each of the first and second signal paths includes a filter and a transmission line between the corresponding input and the filter.

31. The RF circuit of claim 30 wherein the filter includes a band-pass filter.

32. The RF circuit of claim 31 wherein the band-pass filter is a surface acoustic wave (SAW) filter.

33. The RF circuit of claim 29 wherein the approximately zero impedance of the corresponding signal path is at least in part due a selected length of the transmission line.

34. The RF circuit of claim 29 wherein the input of the first signal path is at the first node, and the input of the second signal path is at the second node.

35. The RF circuit of claim 24 further comprising a first grounding switch between the first node of the first signal path and ground, and a second grounding switch between the second of the second signal path and ground, the first and second grounding switches configured to allow a carrier-aggregation mode of operation or non-carrier-aggregation modes of operation.

36. The RF circuit of claim 35 wherein each of the first and second grounding switches is open for the carrier-aggregation mode of operation.

37. The RF circuit of claim 35 wherein the first grounding switch is open and the second grounding switch is closed for a non-carrier-aggregation operation in the first frequency band, and the second grounding switch is open and the first grounding switch is closed for a non-carrier-aggregation operation in the second frequency band.

38. The RF circuit of claim 35 wherein the matched impedance has a value of approximately 50 Ohms.

39. The RF circuit of claim 35 wherein the first frequency band includes band B2 and the second frequency band includes band B4.

40. The RF circuit of claim 39 wherein the first frequency band further includes band B25.

41. A method for routing radio-frequency (RF) signals, the method comprising:

presenting a band-dependent impedance at a first node of a first signal path for a first frequency band and at second node of a second signal path for a second frequency band, the band-dependent impedance including an approximately zero impedance for an out-of-band signal for each of the first and second frequency bands;

receiving an RF signal having the out-of-band signal for each of the first and second frequency bands; and

excluding the out-of-band signal from each of the first and second signal paths with a coupling circuit, based on the approximately zero impedance presented by the corresponding signal path, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground.

42. The method of claim 41 wherein the band-dependent impedance further includes a matched impedance for an in-band signal for each of the first and second frequency bands.

43. The method of claim 42 further comprising 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.

44. A carrier-aggregation system having a coupling circuit and configured to exclude an out-of-band signal in each of first and second signal paths by an out-of-band impedance of approximately zero presented by the signal path, the coupling circuit including a first inductance L1 that couples a common node and a node of the first signal path, a first capacitance C1 that couples the node of the first signal path and a ground, a second capacitance C2 that couples the common node and a node of the second signal path, and a second inductance L2 that couples the node of the second signal path and the ground.

45. The carrier-aggregation system of claim 44 wherein the carrier-aggregation system is further configured to include an in-band signal in each of the first and second signal paths by a matched in-band impedance presented by the signal path.

46. The carrier-aggregation system of claim 45 wherein the out-of-band impedance of approximately zero is obtained by a net impedance adjustment based on a tendency of impedance change associated with a transmission property of the respective signal path.

47. The carrier-aggregation system of claim 46 wherein each of the first and second signal paths includes a band-pass filter.

48. The carrier-aggregation system of claim 47 wherein the tendency of impedance change includes a change towards a zero impedance from an impedance presented by the respective band-pass filter.

49. The carrier-aggregation system of claim 48 wherein the net impedance adjustment provides an impedance of approximately zero for the respective signal path for the out-of-band signal.

50. The carrier-aggregation system of claim 49 wherein the approximately zero impedance of the respective signal path for the out-of-band signal is obtained at least in part by a selected length of a transmission line associated with the respective band-pass filter.

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

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 configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

52. The RF module of claim 51 wherein each of the first and second signal paths includes a filter and a transmission line between the corresponding input and the filter.

53. The RF module of claim 52 wherein the first and second filters are configured to provide a diplexed output.

54. The RF module of claim 53 wherein the RF circuit further includes a low-noise amplifier configured to operate in the first and second frequency bands, the low-noise amplifier having an input configured to receive the diplexed output of the first and second filters.

55. A method for fabricating a radio-frequency (RF) module, the method comprising:

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 including a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.

56. A wireless device comprising:

a receiver configured to process RF signals;

a front-end module in communication with the receiver, and including a carrier-aggregation system, the carrier-aggregation system including a first signal path configured to present an approximately zero impedance at a first node for a signal out of a first frequency band, and a second signal path configured to present an approximately zero impedance at a second node for a signal out of a second frequency band, the RF circuit further including a coupling circuit that couples the inputs of the first and second signal paths, the coupling circuit including a first inductance L1 that couples a common node and the first node, a first capacitance C1 that couples the first node and a ground, a second capacitance C2 that couples the common node and the second node, and a second inductance L2 that couples the second node and the ground, values of L1, C1, C2 and L2 selected such that the approximately zero impedance of each signal path results in the corresponding signal to be substantially excluded from the signal path.