BALUNS WITH INTEGRATED MATCHING NETWORKS

BACKGROUND

Technical Field

[0001] Embodiments of the invention relate to electronic systems, and in particular, to radio frequency (RF) electronics.

Description of Related Technology

[0002] A balun can be used to convert a single-ended RF signal to a differential RF signal, or vice versa. Examples of RF communication systems with one or more baluns include, but are not limited to, mobile phones, tablets, base stations, network access points, customer-premises equipment (CPE), laptops, and wearable electronics.

[0003] Baluns can be included in RF communication systems to provide conversion of RF signals of a wide range of frequencies. For example, baluns can handle RF signals in a frequency range of about 30 kHz to 300 GHz, such as in the range of about 410 MHz to about 7.125 GHz for fifth generation (5G) communications using Frequency Range 1 (FR1) or in the range of about 24.25 GHz to 52.6 GHz for 5G communications using Frequency Range 2 (FR2).

SUMMARY

[0004] In an aspect, the present disclosure relates to a balun. The balun includes a first pair of coupled lines including a first conductive line and a second conductive line, a second pair of coupled lines including a third conductive line and a fourth conductive line, and a transmission line connecting the first conductive line of the first pair of coupled lines to the third conductive line of the second pair of conductive lines.

[0005] In several examples, the first pair of conductive lines and the second pair of conductive lines have different lengths.

[0006] In various examples, the first pair of conductive lines and the second pair of conductive lines have different odd-mode impedances.

[0007] In some examples, the first pair of conductive lines and the second pair of conductive lines have different even-mode impedances.

[0008] In several examples, the first pair of conductive lines, the second pair of conductive lines, and the transmission line are implemented to provide input matching.

[0009] In various examples, the first pair of conductive lines, the second pair of conductive lines, and the transmission line are implemented to provide output matching.

[0010] In a number of examples, the transmission line includes a coil.

[0011] In some examples, the balun further includes a first port connected to an end of the first conductive line opposite the transmission line, a second port connected to the second conductive line of the first pair of conductive lines, and a third port connected to the fourth conductive line of the second pair of conductive lines.

[0012] According to a number of examples, the first port is as an unbalanced terminal for a single-ended signal, the second port is as a positive terminal for a differential signal, and the third port is as a negative terminal for the differential signal.

[0013] In accordance with several examples, an end of the third conductive line opposite the transmission line is connected to a reference voltage.

[0014] According to various examples, an end of the second conductive line opposite the second port is connected to a reference voltage.

[0015] In accordance with a number of examples, an end of the fourth conductive line opposite the third port is connected to a reference voltage.

[0016] According to a number of examples, the first port is configured to receive a single-ended signal from an amplifier.

[0017] In accordance with several examples, the first port is configured to output a single-ended signal to an amplifier.

[0018] According to various examples, the second port and the third port are configured to receive a differential signal from an amplifier.

[0019] In accordance with a number of examples, the second port and the third port are configured to provide a differential signal to an amplifier.

[0020] In another aspect, the present disclosure relates to a wireless device. The wireless device includes a transceiver and a front-end system coupled to the transceiver. The front-end system includes a balun that includes a first pair of coupled lines including a first conductive line and a second conductive line, a second pair of coupled lines including a third conductive line and a fourth conductive line, and a transmission line connecting the first

conductive line of the first pair of coupled lines to the third conductive line of the second pair of conductive lines.

[0021] In various examples, the first pair of conductive lines and the second pair of conductive lines have different lengths.

[0022] In several examples, the first pair of conductive lines and the second pair of conductive lines have different odd-mode impedances.

[0023] In a number of examples, the first pair of conductive lines and the second pair of conductive lines have different even-mode impedances.

[0024] In some examples, the first pair of conductive lines, the second pair of conductive lines, and the transmission line are implemented to provide input matching.

[0025] In various examples, the first pair of conductive lines, the second pair of conductive lines, and the transmission line are implemented to provide output matching.

[0026] In several examples, the transmission line includes a coil.

[0027] In some examples, the balun further includes a first port connected to an end of the first conductive line opposite the transmission line, a second port connected to the second conductive line of the first pair of conductive lines, and a third port connected to the fourth conductive line of the second pair of conductive lines.

[0028] According to a number of examples, the first port is an unbalanced terminal for a single-ended signal, the second port is a positive terminal for a differential signal, and the third port is a negative terminal for the differential signal.

[0029] In accordance with several examples, an end of the third conductive line opposite the transmission line is connected to a reference voltage.

[0030] According to various examples, an end of the second conductive line opposite the second port is connected to a reference voltage.

[0031] In accordance with a number of examples, an end of the fourth conductive line opposite the third port is connected to a reference voltage.

[0032] According to various examples, the front end system further includes an amplifier configured to receive a single-ended signal from the first port.

[0033] In accordance with several examples, the front end system further includes an amplifier configured to provide a single-ended signal to the first port.

[0034] According to a number of examples, the front end system further includes an amplifier configured to receive a differential signal from the second port and the third port.

[0035] In accordance with several examples, the front end system further includes an amplifier configured to provide a differential signal to the second port and the third port.

[0036] In another aspect, the present disclosure relates to a method of signal conversion in a balun. The method includes providing coupling between a first conductive line and a second conductive line of a first pair of coupled lines, providing coupling between a third conductive line and a fourth conductive line of a second pair of coupled lines, and using a transmission line to provide a signal path from the first conductive line of the first pair of coupled lines to the third conductive line of the second pair of conductive lines.

[0037] In various examples, the first pair of conductive lines and the second pair of conductive lines have different lengths.

[0038] In several examples, the first pair of conductive lines and the second pair of conductive lines have different odd-mode impedances.

[0039] In a number of examples, the first pair of conductive lines and the second pair of conductive lines have different even-mode impedances.

[0040] In some examples, the method further includes providing input matching using the first pair of conductive lines, the second pair of conductive lines, and the transmission line.

[0041] In various examples, the method further includes providing output matching using the first pair of conductive lines, the second pair of conductive lines, and the transmission line.

[0042] In some examples, the method further includes providing a first port on an end of the first conductive line opposite the transmission line, providing a second port on an end of the second conductive line of the first pair of conductive lines, and providing a third port on an end of the fourth conductive line of the second pair of conductive lines.

[0043] According to a number of examples, the method further includes using the first port as an unbalanced terminal for a single-ended signal, using the second port as a

positive terminal for a differential signal, and using the third port as a negative terminal for the differential signal.

[0044] In accordance with several examples, the method further includes using the first port to receive a single-ended signal from an amplifier.

[0045] According to various examples, the method further includes using the first port to provide a single-ended signal to an amplifier.

[0046] In accordance with a number of examples, the method further includes using the second port and the third port to receive a differential signal from an amplifier.

[0047] According to several examples, the method further includes using the second port and the third port provide a differential signal to an amplifier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0048] Embodiments of this disclosure will now be described, by way of non-limiting example, with reference to the accompanying drawings.

[0049] Figure 1 is a schematic diagram of one example of a communication network.

[0050] Figure 2A is a schematic diagram of one embodiment of a communication system that operates with beamforming.

[0051] Figure 2B is a schematic diagram of one embodiment of beamforming to provide a transmit beam.

[0052] Figure 2C is a schematic diagram of one embodiment of beamforming to provide a receive beam.

[0053] Figure 3A is a schematic diagram of a balun with an integrated matching network according to one embodiment.

[0054] Figure 3B is a schematic diagram of a balun with an integrated matching network according to another embodiment.

[0055] Figure 3C is a schematic diagram of a balun with an integrated matching network according to another embodiment.

[0056] Figure 3D is a schematic diagram of a balun with an integrated matching network according to another embodiment.