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(54) **SINGLE ENDED RECEIVER WITH A MULTI-PORT TRANSFORMER AND SHARED MIXER**

(71) Applicant: **QUALCOMM Incorporated**, San Diego, CA (US)

(72) Inventors: **Wei Zhuo**, San Diego, CA (US); **Ojas M Choksi**, San Diego, CA (US); **Prasad Srinivasa Siva Gudem**, San Diego, CA (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

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(51) **Int. Cl.**

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H04B 1/38	(2015.01)
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H04B 1/00	(2006.01)
H04B 1/18	(2006.01)

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(58) **Field of Classification Search**
CPC H04B 1/005; H04B 1/18; H03D 7/1466; H03D 7/14; H03H 7/42; H03H 7/463; H01P 5/12
USPC 455/334, 179.1, 303, 292, 326, 333, 455/180.1, 293, 266, 130, 143, 168.1, 455/176.1, 225, 230, 252.1, 275; 336/223, 336/200, 232; 343/700, 795, 859; 333/25
See application file for complete search history.

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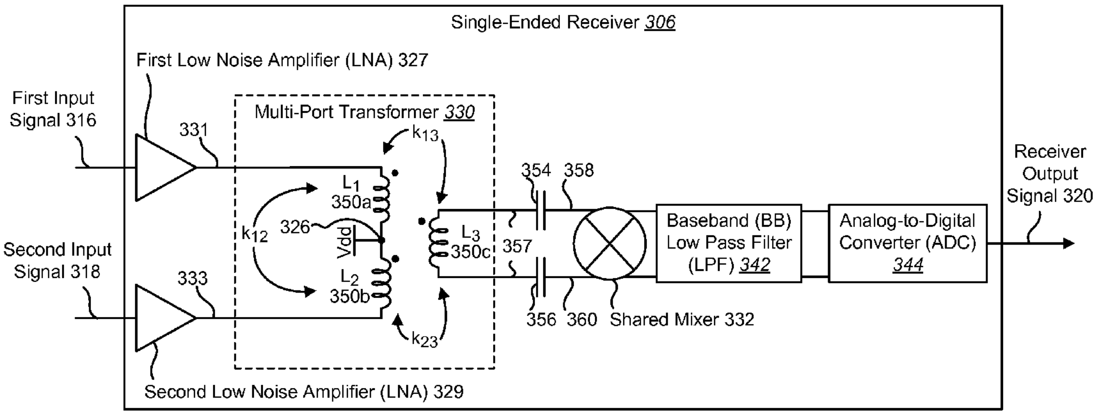
Primary Examiner — Pablo Tran
(74) *Attorney, Agent, or Firm* — Rupit M. Patel

(57) **ABSTRACT**

A single-ended receiver is described. The single-ended receiver includes a multi-port transformer that outputs a differential signal. The multi-port transformer includes a first primary coil that is coupled to an output of a first low noise amplifier. The multi-port transformer also includes a second primary coil that is coupled to an output of a second low noise amplifier. The multi-port transformer further includes a first secondary coil. The single-ended receiver also includes a shared mixer that receives the differential signal from the multi-port transformer.

42 Claims, 10 Drawing Sheets



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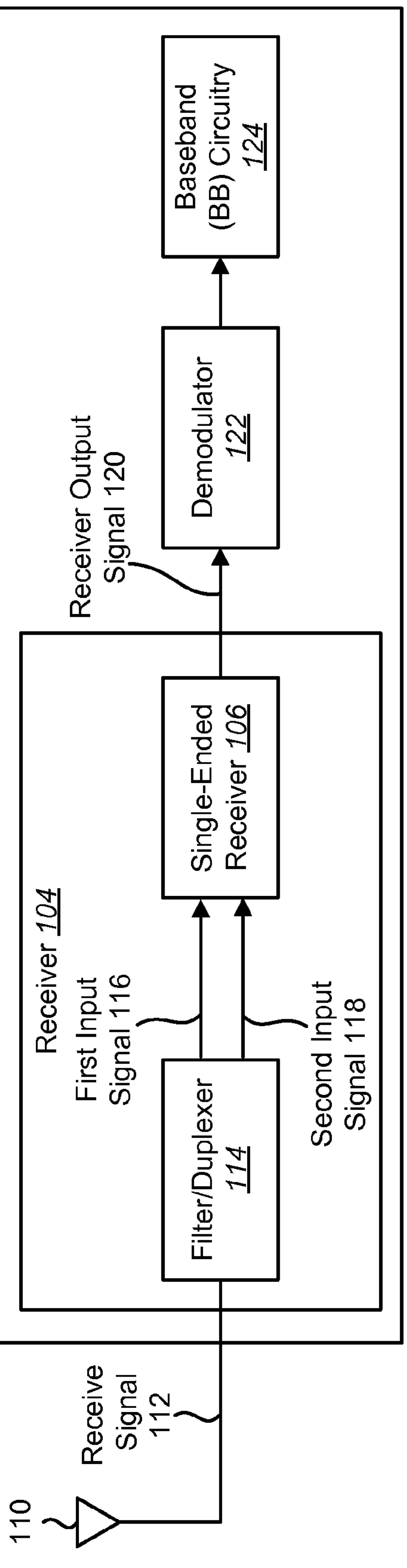
Wireless Device 102
Baseband (BB) Circuitry 124
Demodulator 122
Receiver Output Signal 120
Receiver 104
Single-Ended Receiver 106
First Input Signal 116
Second Input Signal 118
Filter/Duplexer 114
Receive Signal 112
110

FIG. 1

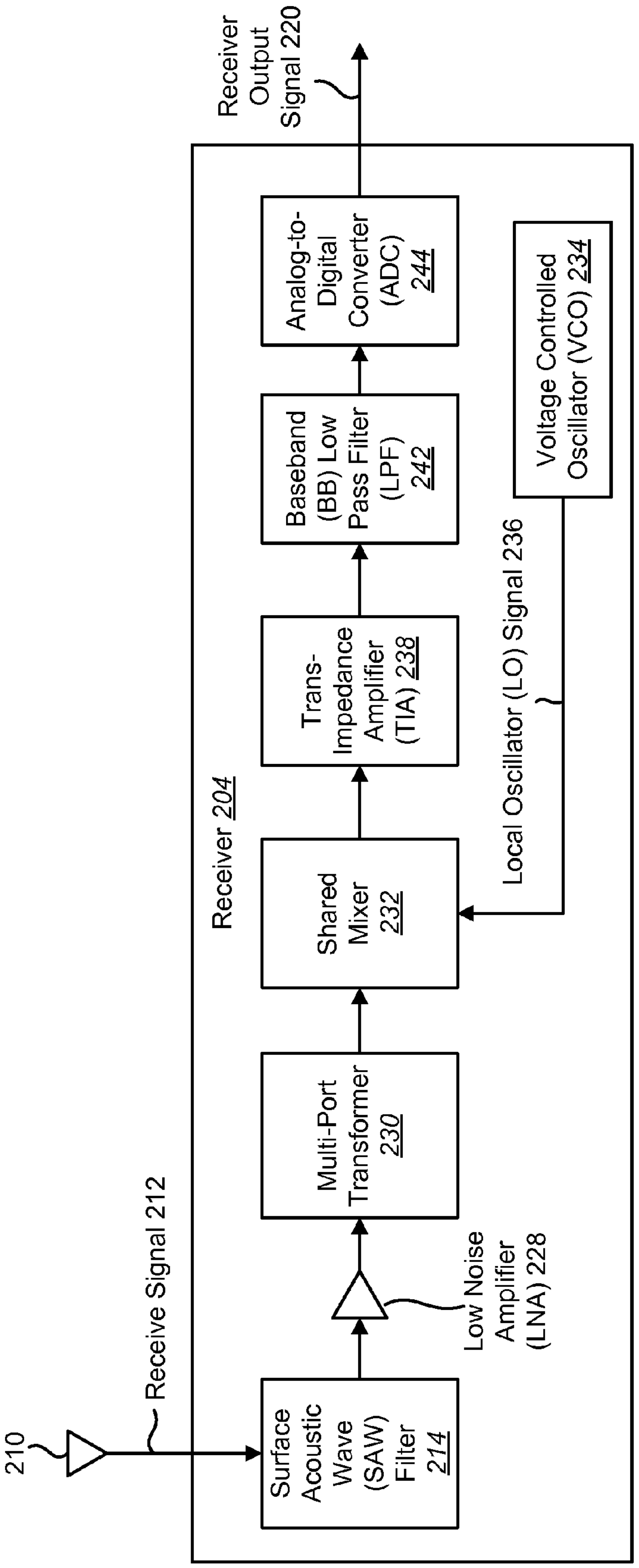
210
Receive Signal 212
Surface Acoustic Wave (SAW) Filter 214
Low Noise Amplifier (LNA) 228
Multi-Port Transformer 230
Shared Mixer 232
Receiver 204
Local Oscillator (LO) Signal 236
Trans-Impedance Amplifier (TIA) 238
Baseband (BB) Low Pass Filter (LPF) 242
Voltage Controlled Oscillator (VCO) 234
Analog-to-Digital Converter (ADC) 244
Receiver Output Signal 220

FIG. 2

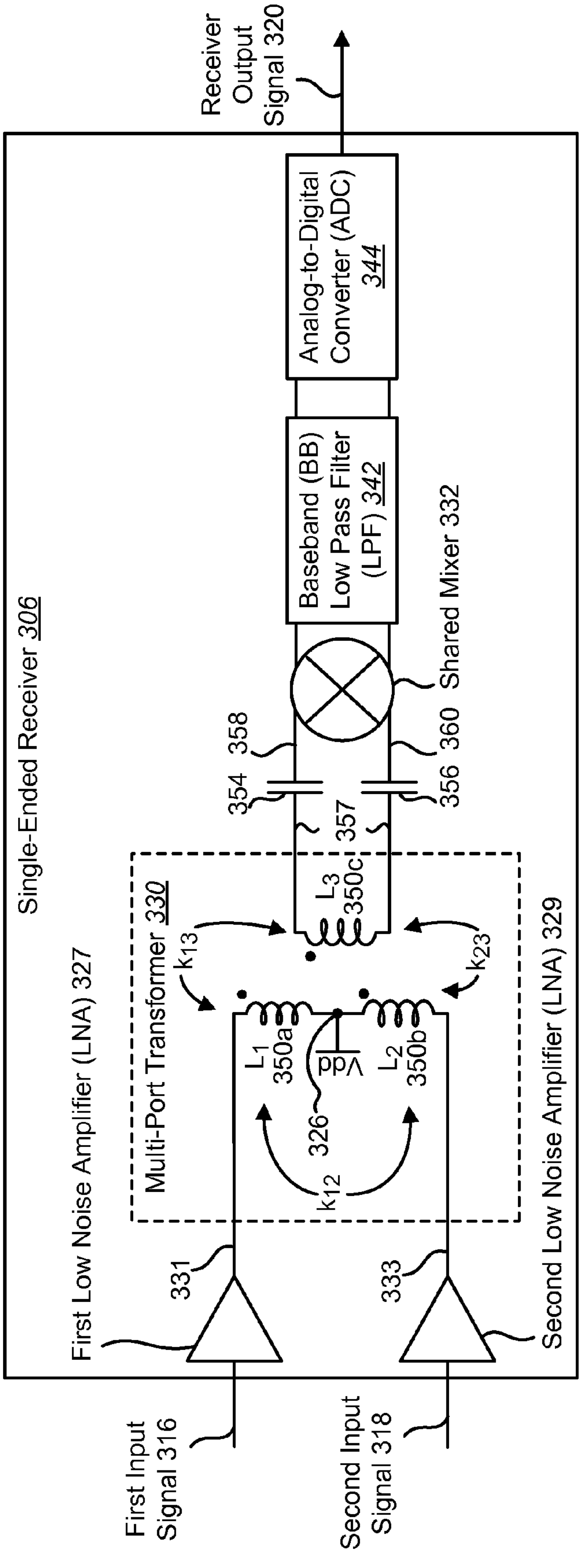
Receiver Output Signal 320
Single-Ended Receiver 306
Analog-to-Digital Converter (ADC) 344
Baseband (BB) Low Pass Filter (LPF) 342
Shared Mixer 332
358
360
354
356
357
Multi-Port Transformer 330
k13
k23
L3 350c
L1 350a
L2 350b
Vdd
326
k12
First Low Noise Amplifier (LNA) 327
Second Low Noise Amplifier (LNA) 329
331
333
First Input Signal 316
Second Input Signal 318

FIG. 3

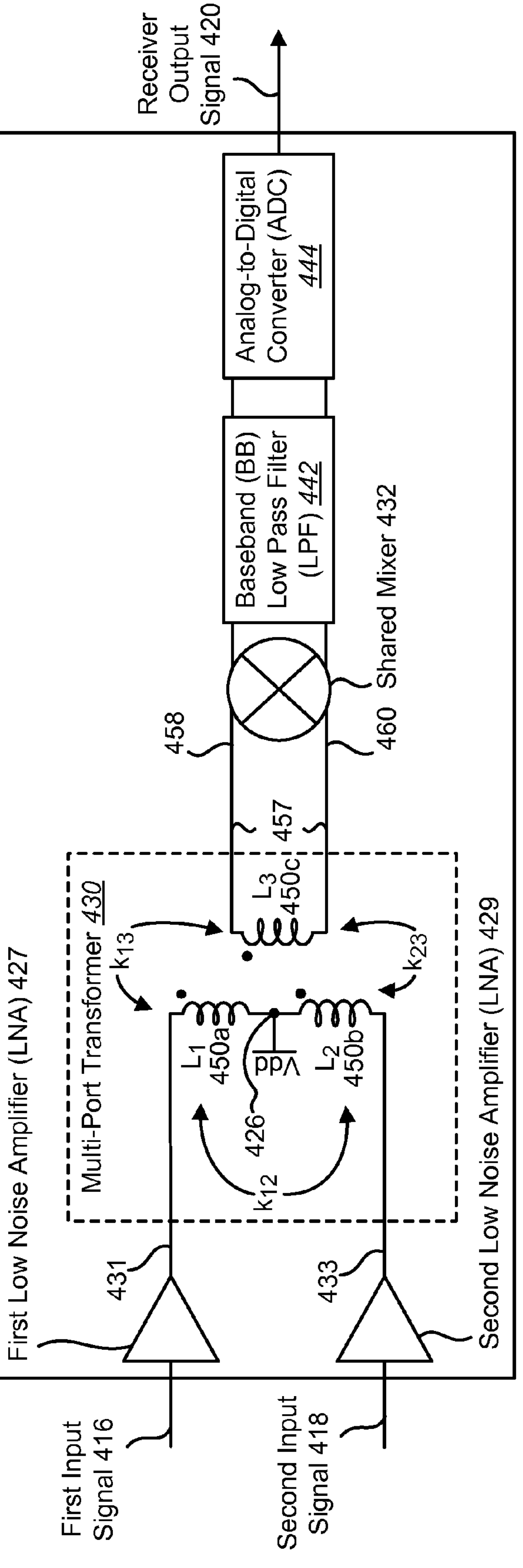
Receiver Output Signal 420
Single-Ended Receiver 406
Analog-to-Digital Converter (ADC) 444
Baseband (BB) Low Pass Filter (LPF) 442
Shared Mixer 432
458
460
457
Multi-Port Transformer 430
k_{13}
k_{23}
L_3 450c
L_1 450a
Vdd
L_2 450b
426
k_{12}
First Low Noise Amplifier (LNA) 427
Second Low Noise Amplifier (LNA) 429
431
433
First Input Signal 416
Second Input Signal 418

FIG. 4

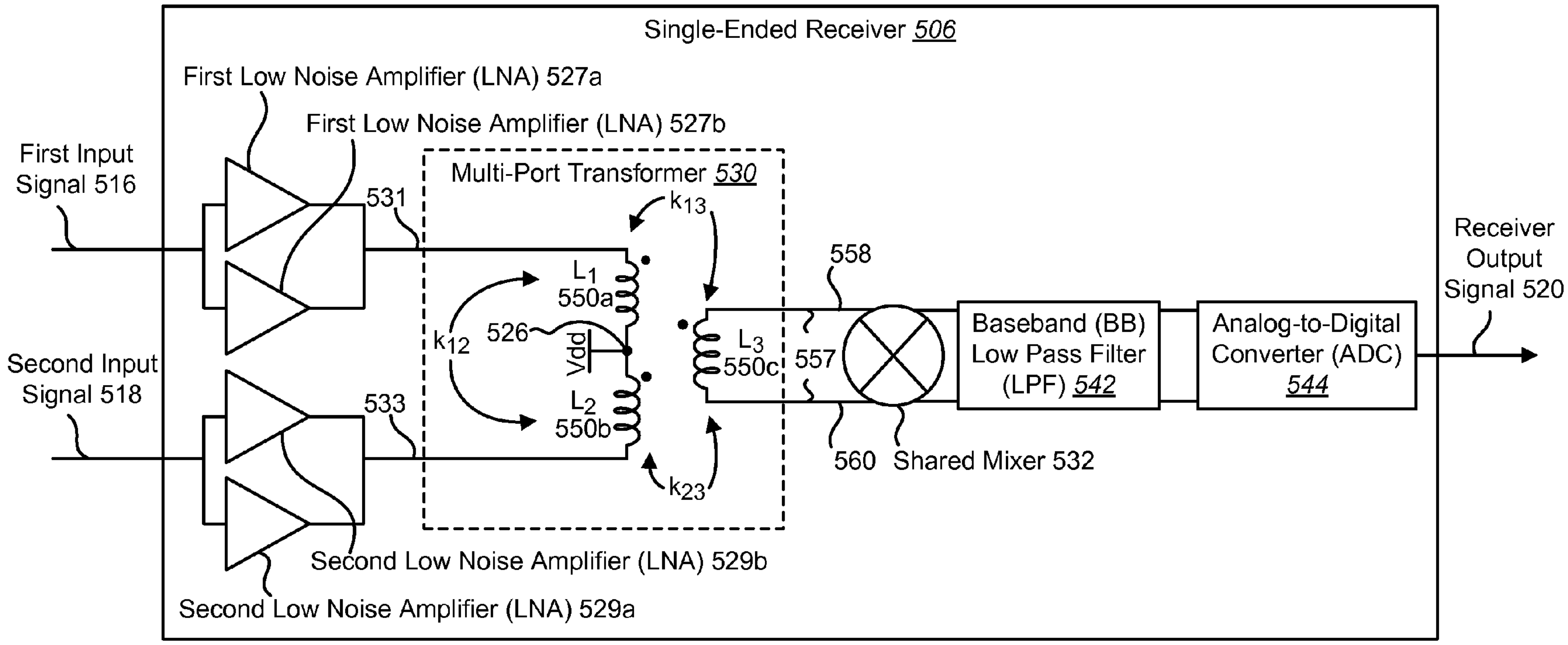
Single-Ended Receiver 506
First Low Noise Amplifier (LNA) 527a
First Low Noise Amplifier (LNA) 527b
First Input Signal 516
Second Input Signal 518
531
533
Multi-Port Transformer 530
k_{13}
k_{12}
k_{23}
526
Vdd
L_1 550a
L_2 550b
L_3 550c
557
558
560
Shared Mixer 532
Baseband (BB) Low Pass Filter (LPF) 542
Analog-to-Digital Converter (ADC) 544
Receiver Output Signal 520
Second Low Noise Amplifier (LNA) 529b
Second Low Noise Amplifier (LNA) 529a

FIG. 5

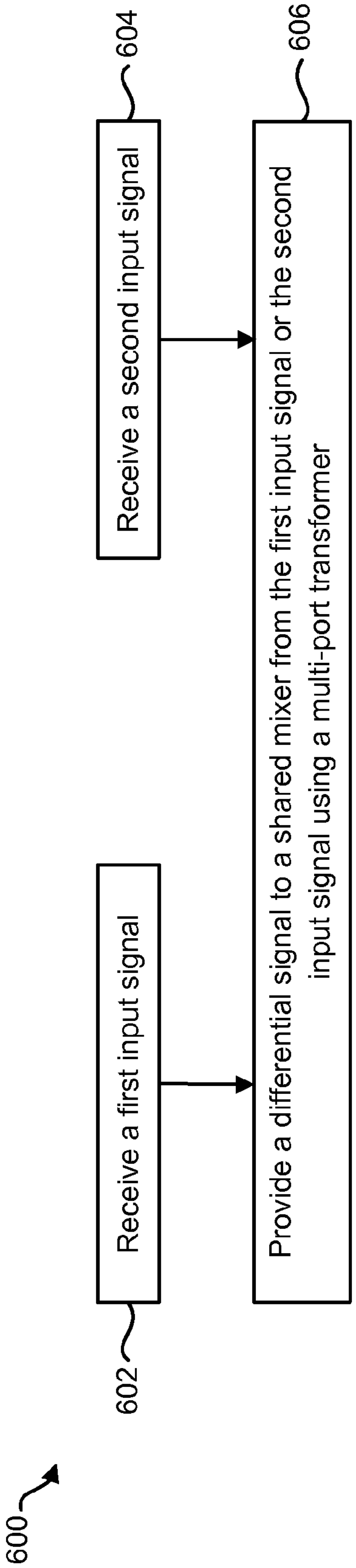
600
602
Receive a first input signal
604
Receive a second input signal
606
Provide a differential signal to a shared mixer from the first input signal or the second input signal using a multi-port transformer

FIG. 6

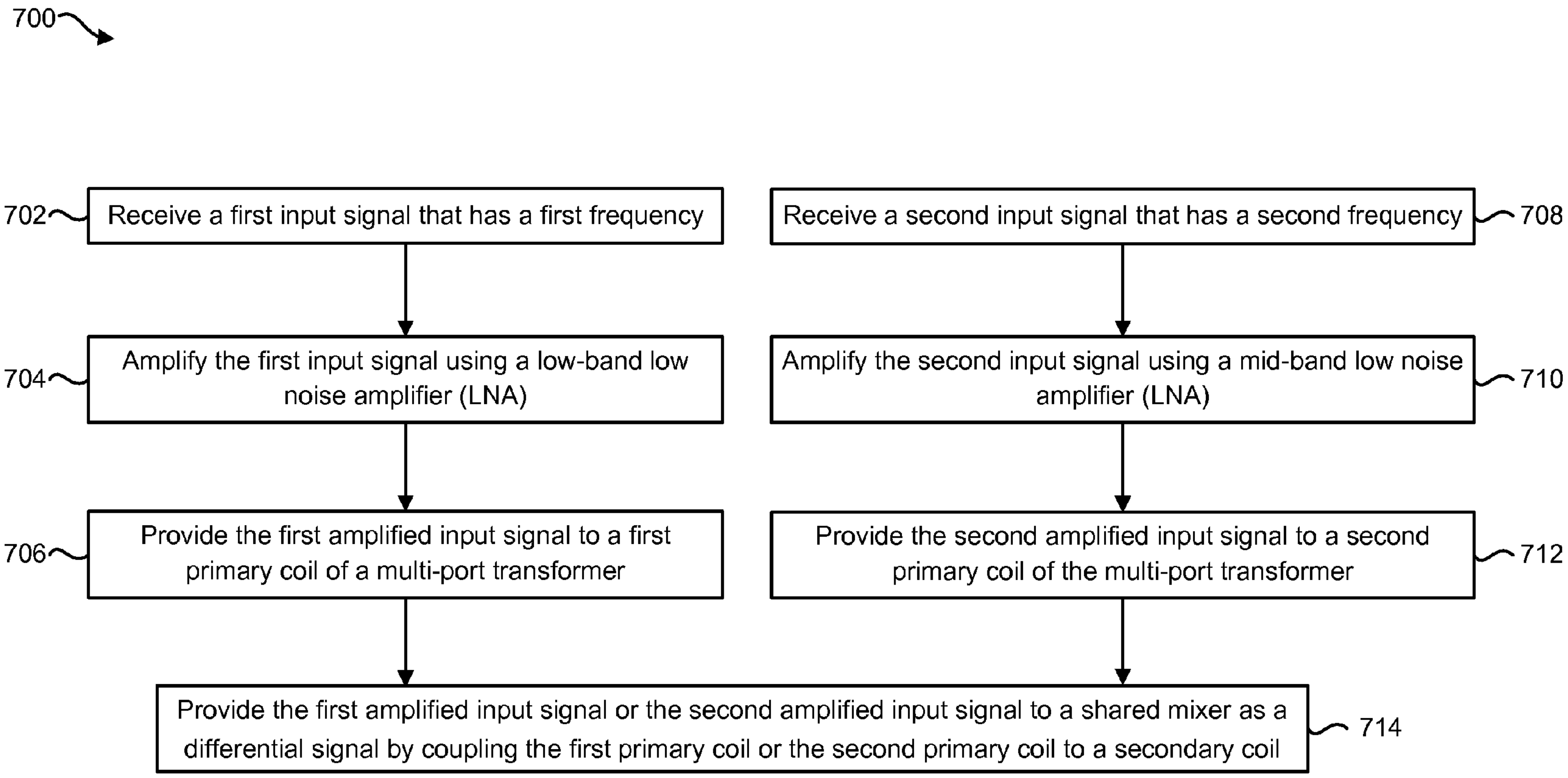
700
702
Receive a first input signal that has a first frequency
704
Amplify the first input signal using a low-band low noise amplifier (LNA)
706
Provide the first amplified input signal to a first primary coil of a multi-port transformer
708
Receive a second input signal that has a second frequency
710
Amplify the second input signal using a mid-band low noise amplifier (LNA)
712
Provide the second amplified input signal to a second primary coil of the multi-port transformer
714
Provide the first amplified input signal or the second amplified input signal to a shared mixer as a differential signal by coupling the first primary coil or the second primary coil to a secondary coil

FIG. 7

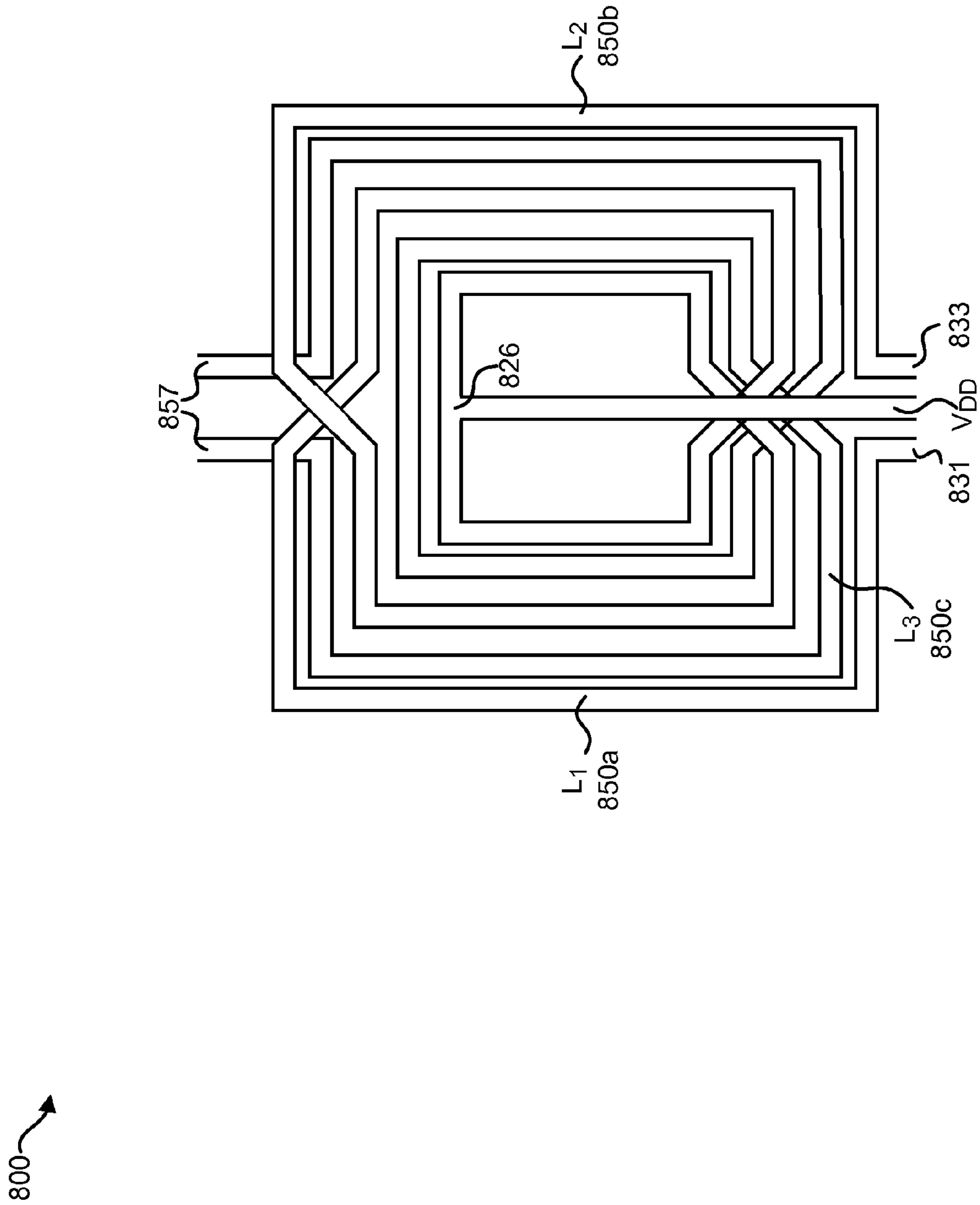

FIG. 8

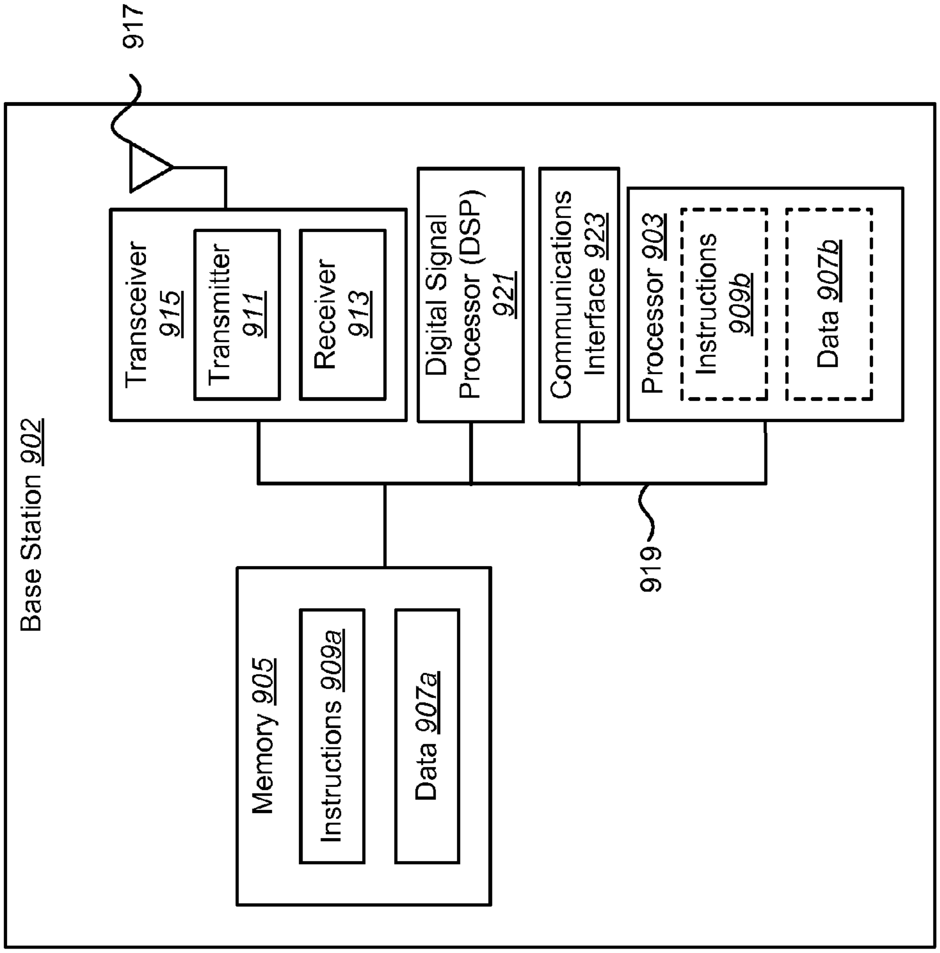
917
Base Station 902
Transceiver 915
Transmitter 911
Receiver 913
Digital Signal Processor (DSP) 921
Communications Interface 923
Processor 903
Instructions 909b
Data 907b
919
Memory 905
Instructions 909a
Data 907a

FIG. 9

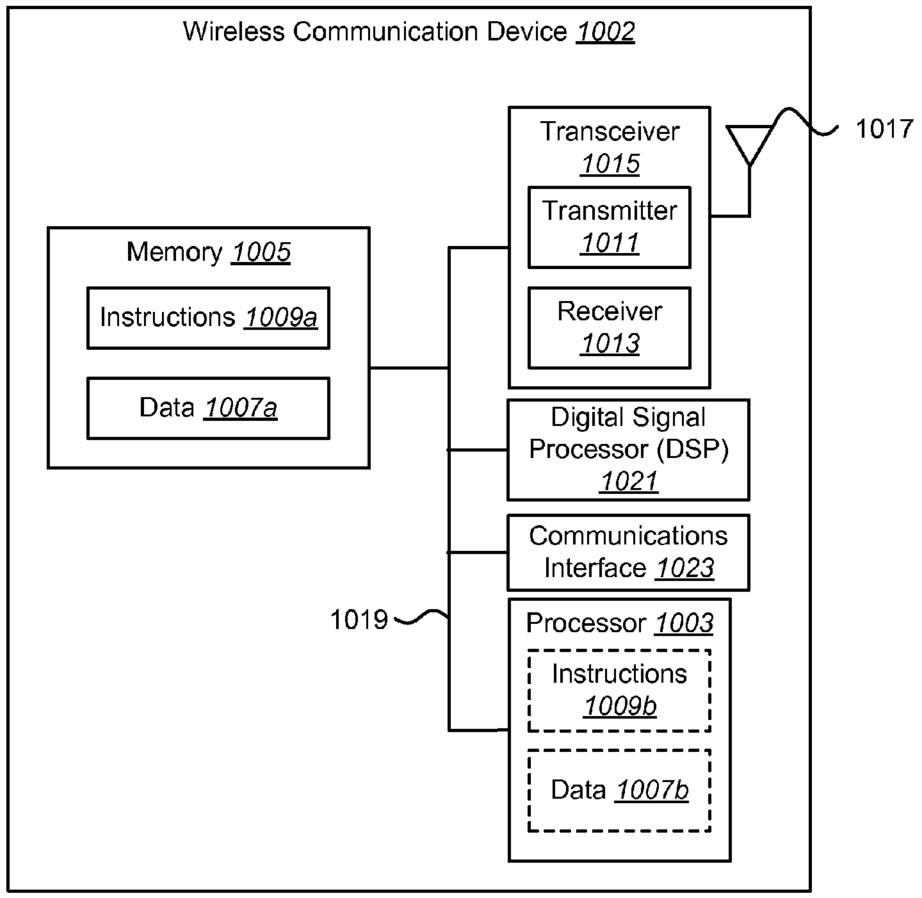
Wireless Communication Device 1002
Memory 1005
Instructions 1009a
Data 1007a
Transceiver 1015
Transmitter 1011
Receiver 1013
1017
Digital Signal Processor (DSP) 1021
Communications Interface 1023
1019
Processor 1003
Instructions 1009b
Data 1007b

FIG. 10

SINGLE ENDED RECEIVER WITH A MULTI-PORT TRANSFORMER AND SHARED MIXER

CLAIM OF PRIORITY UNDER 35 U.S.C. §119

The present application for patent claims priority to Provisional Application No. 61/618,494, entitled “Single-ended receiver with a multi-port transformer and shared mixer” filed Mar. 30, 2012, and assigned to the assignee hereof and hereby expressly incorporated by reference herein.

TECHNICAL FIELD

The present disclosure relates generally to electronic devices for communication systems. More specifically, the present disclosure relates to systems and methods for a single-ended receiver with a multi-port transformer and shared mixer.

BACKGROUND

Wireless communication systems are widely deployed to provide various types of communication content such as voice, video, data, and so on. These systems may be multiple-access systems capable of supporting simultaneous communication of multiple terminals with one or more base stations.

A terminal or a base station may include one or more integrated circuits. These integrated circuits may include analog and digital circuitry necessary for wireless communication. Such circuitry may include inductors. As the technology used to build integrated circuits progresses, some elements on the integrated circuit such as transistors continue to decrease in size. However, some elements, such as passive elements, have not decreased in size as quickly. Therefore, benefits may be realized by simplifying an integrated circuit.

SUMMARY OF THE INVENTION

A single-ended receiver is described. The single-ended receiver includes a multi-port transformer that outputs a differential signal. The multi-port transformer includes a first primary coil that is coupled to an output of a first low noise amplifier. The multi-port transformer also includes a second primary coil that is coupled to an output of a second low noise amplifier. The multi-port transformer further includes a first secondary coil. The single-ended receiver also includes a shared mixer that receives the differential signal from the multi-port transformer.

The multi-port transformer may include a first coupling between the first primary coil and the second primary coil, a second coupling between the first primary coil and the first secondary coil and a third coupling between the second primary coil and the first secondary coil. The first low noise amplifier may receive a first input signal and the second low noise amplifier may receive a second input signal.

The first input signal may be active, the second input signal may be inactive and the multi-port transformer may output the differential signal based on the first input signal. The first input signal may be inactive, the second input signal may be active and the multi-port transformer outputs the differential signal based on the second input signal. The first input signal may include a first frequency and the second input signal may include a second frequency.

The multi-port transformer may further include a center tap between the first primary coil and the second primary coil. The first low noise amplifier may include a low-frequency low noise amplifier for operation with a low-frequency signal and the second low noise amplifier may include a high-frequency low noise amplifier for operation with a high-frequency signal. The first low noise amplifier may receive a low-frequency input signal and the second low noise amplifier may receive a high-frequency second signal.

The single-ended receiver may also include a baseband low pass filter coupled to the shared mixer. The single-ended receiver of may also include an analog-to-digital converter coupled to the baseband low pass filter. The baseband low pass filter may output a receiver output signal.

The first secondary coil may be coupled to a first shared mixer input and a second shared mixer input of the shared mixer. The single-ended receiver may also include a first capacitor coupled between the first secondary coil and the first shared mixer input and a second capacitor coupled between the first secondary coil and the second shared mixer input.

The single-ended receiver may include an additional first low noise amplifier parallel with the first low noise amplifier and an additional second low noise amplifier parallel with the second low noise amplifier. The additional first low noise amplifier may receive a first input signal. The additional second low noise amplifier may receive a second input signal. The first input signal may have a first frequency and the second input signal has a second frequency.

A method for receiving a wireless signal is also described. A first input signal is received. A second input signal is received. A differential signal is provided to a shared mixer from one of the first input signal and the second input signal using a multi-port transformer

An apparatus is also described. The apparatus includes means for receiving a first input signal. The apparatus also includes means for receiving a second input signal. The apparatus further includes means for providing a differential signal to a shared mixer from one of the first input signal and the second input signal using a multi-port transformer.

A computer-program product for receiving a wireless signal is also described. The computer-program product includes a non-transitory computer-readable medium having instructions for causing a wireless device to receive a first input signal. The computer-readable medium also includes instructions for causing the wireless device to receive a second input signal. The computer-readable medium further includes instructions for causing the wireless device to provide a differential signal to a shared mixer using a multi-port transformer from one of the first input signal and the second input signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a wireless device that uses a single-ended receiver;

FIG. **2** is a block diagram illustrating one configuration of a receiver for use in the present systems and methods;

FIG. **3** is a block diagram illustrating one configuration of a single-ended receiver;

FIG. **4** is a block diagram illustrating another configuration of a single-ended receiver;

FIG. **5** is a block diagram illustrating yet another configuration of a single-ended receiver;

FIG. **6** is a flow diagram of a method for receiving a wireless signal using a single-ended receiver;

FIG. **7** is a flow diagram of another method for receiving a wireless signal using a single-ended receiver;

FIG. **8** is a layout diagram illustrating one configuration of a single-ended receiver;

FIG. **9** illustrates certain components that may be included within a base station; and

FIG. **10** illustrates certain components that may be included within a wireless communication device.

DETAILED DESCRIPTION

FIG. **1** is a block diagram illustrating a wireless device **102** that uses a single-ended receiver **106**. The wireless device **102** may be a wireless communication device or a base station.

A wireless communication device may also be referred to as, and may include some or all of the functionality of, a terminal, an access terminal, a user equipment (UE), a subscriber unit, a station, etc. A wireless communication device may be a cellular phone, a personal digital assistant (PDA), a wireless device, a wireless modem, a handheld device, a laptop computer, a PC card, compact flash, an external or internal modem, a wireline phone, etc. A wireless communication device may be mobile or stationary. A wireless communication device may communicate with zero, one or multiple base stations on a downlink and/or an uplink at any given moment. The downlink (or forward link) refers to the communication link from a base station to a wireless communication device, and the uplink (or reverse link) refers to the communication link from a wireless communication device to a base station. Uplink and downlink may refer to the communication link or to the carriers used for the communication link.

The wireless communication device may operate in a wireless communication system that includes other wireless devices, such as base stations. A base station is a station that communicates with one or more wireless communication devices. A base station may also be referred to as, and may include some or all of the functionality of, an access point, a broadcast transmitter, a Node B, an evolved Node B, etc. Each base station provides communication coverage for a particular geographic area. A base station may provide communication coverage for one or more wireless communication devices. The term "cell" can refer to a base station and/or its coverage area, depending on the context in which the term is used.

Communications in a wireless communication system (e.g., a multiple-access system) may be achieved through transmissions over a wireless link. Such a communication link may be established via a single-input and single-output (SISO) or a multiple-input and multiple-output (MIMO) system. A multiple-input and multiple-output (MIMO) system includes transmitter(s) and receiver(s) equipped, respectively, with multiple (NT) transmit antennas and multiple (NR) receive antennas for data transmission. SISO systems are particular instances of a multiple-input and multiple-output (MIMO) system. The multiple-input and multiple-output (MIMO) system can provide improved performance (e.g., higher throughput, greater capacity or improved reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

The wireless communication system may utilize both single-input and multiple-output (SIMO) and multiple-input and multiple-output (MIMO). The wireless communication system may be a multiple-access system capable of supporting communication with multiple wireless communication devices by sharing the available system resources (e.g., bandwidth and transmit power). Examples of such multiple-access systems include code division multiple access (CDMA) systems, wideband code division multiple access (W-CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems and spatial division multiple access (SDMA) systems.

The wireless device **102** may include receiver **104**, a demodulator **122** and baseband (BB) circuitry **124**. The receiver **104** may include a filter/duplexer **114**. The filter/duplexer **114** may be a surface acoustic wave (SAW) filter/duplexer. The filter/duplexer **114** may receive a receive signal **112** from an antenna **110**. The receive signal **112** may be a wireless signal. The filter/duplexer **114** may process and output the receive signal **112** as a first input signal **116** and a second input signal **118**. The filter/duplexer **114** may produce the first input signal **116** and the second input signal **118** based on the frequency of the receive signal **112**. For example, the filter/duplexer **114** may process and output incoming frequencies under 1 gigahertz (GHz) as the first input signal **116** and incoming frequencies over 1 GHz as the second input signal **118**. In some configurations, a duplexer and/or switch may be used in place of, or in addition to, the filter/duplexer **114**.

The first input signal **116** may be a low-frequency signal and the second input signal **118** may be a high-frequency signal. In some configurations, the filter/duplexer **114** may process and output a number of input signals. For example, the filter/duplexer **114** may output up to six signals.

The receiver **104** may include a single-ended receiver **106**. The single-ended receiver **106** may receive the first input single **116** and/or the second input signal **118** from the filter/duplexer **114**. As a result, the single-ended receiver **106** is not required to receive a differential signal. The single-ended receiver **106** may operate using a single signal front-end. In other words, only a single input signal is required for the single-ended receiver **106**. This is in contrast to a differential front-end, which requires multiple input signals to operate.

One benefit of using a single-ended receiver **106** is that the amount of circuit components may be reduced. For example, only one input pin is required for a single-ended receiver **106**. In contrast, two input pins are required for a differential receiver to operate. Thus, the number of input pins required is reduced when the receiver **104** includes a single-ended receiver **106**.

A receiver **104** that has less components may consume a smaller die/chip area. Additionally, using fewer components requires less power to be consumed by the wireless device **102**. Thus, the use of a single-ended receiver **106** in a receiver **104** instead of a differential-ended receiver may reduce the power consumption of a wireless device **102**.

The single-ended receiver **106** may provide a receiver output signal **120** to the demodulator **122**. The demodulator **122** may provide a demodulated signal to the baseband (BB) circuitry **124**. The baseband (BB) circuitry **124** may further process the demodulated signal. For example, the baseband (BB) circuitry **124** may further condition the demodulated signal to obtain voice and/or data.

In some configurations of a receiver **104**, separate transformers and mixers are required to process each input signal. In other words, for two received signals, two sets of transformers and mixers are required. Thus, as the number of input signals increases, the number of transformers and mixers in the receiver **104** also increases. This then results in an increase in die/chip area and an increase in the amount of current required.

In another configuration of a receiver **104**, switches may be employed to switch transformers from processing the first input signal **116** to the second input signal **118**. However, type of configuration degrades the quality factor (Q) of the transformer and hence, degrades the signal-to-noise ratio. (SNR). Further, this type of configuration also requires that multiple transformers be used. Thus, benefits may be realized by using a single-ended receiver **106** with a multi-port transformer and a shared mixer.

FIG. **2** is a block diagram illustrating one configuration of a receiver **204** for use in the present systems and methods. The receiver **204** of FIG. **2** may illustrate one configuration of the receiver **104** described in connection with FIG. **1**. The receiver **204** may include a surface acoustic wave (SAW) filter **214**, a low noise amplifier (LNA) **228**, a multi-port transformer **230**, a shared mixer **232**, a trans-impedance amplifier (TIA) **238**, a baseband (BB) low pass filter (LPF) **242**, an analog-to-digital converter (ADC) **244** and a voltage controlled oscillator (VCO) **234**.

The receiver **204** may obtain a receive signal **212** using an antenna **210**. The receive signal **212** may include one or more frequencies. The receive signal **212** may be passed through the surface acoustic wave (SAW) filter **214** and the low noise amplifier (LNA) **228**. The amplified signal may then be passed through the multi-port transformer **230** to the shared mixer **232**. The shared mixed **232** may adjust the frequency of the receive signal. The shared mixer **232** may receive a local oscillator (LO) signal **236** from a voltage controlled oscillator (VCO) **234**. The output of the shared mixer **232** may be passed through the trans-impedance amplifier (TIA) **238**, the baseband (BB) low pass filter (LPF) **242** and the analog-to-digital converter (ADC) **244** to obtain a receiver output signal **220**.

FIG. **3** is a block diagram illustrating one configuration of a single-ended receiver **306**. The single-ended receiver **306** of FIG. **3** may illustrate one configuration of the single-ended receiver **106** described in connection with FIG. **1**. The single-ended receiver **306** may include a multi-port transformer **330**, a shared mixer **332**, a baseband (BB) low pass filter (LPF) **342** and an analog-to-digital converter (ADC) **344**. For simplicity, the single-ended receiver **306** is illustrated with only one channel. However, the channel may include an inphase portion and a quadrature portion.

The single-ended receiver **306** uses a multi-port transformer **330** to produce a differential signal **357** to the shared mixer **332**. In one configuration, a low-frequency path and a high-frequency path may share the multi-port transformer **330** and the shared mixer **332**. Thus, in this configuration, the number of circuit elements needed to process a receive signal **112** is reduced while avoiding signal-to-noise ratios (SNR) degradation. As a result, signal routing is simplified and current consumption in the single-ended receiver **306** is reduced.

A smaller die/chip size is required and less power is consumed. Reducing the number of inductor components may be especially helpful in reducing the die/chip size. While active circuit components decrease in size due to the advancement of the technology, the size of passive devices, such as inductors, remain the same. Thus, inductors may dominate the die/chip area used. Reducing the number of necessary inductors in an integrated circuit may have a greater effect in reducing the die/chip area than reducing the number of other circuit elements on a receiver **104**.

The single-ended receiver **306** may receive a first input signal **316** and a second input signal **318**. The first input signal **316** may be provided to a first low noise amplifier (LNA) **327**. The second input signal **318** may be provided to a second low noise amplifier (LNA) **329**. The first low noise amplifier (LNA) **327** and the second low noise amplifier (LNA) **329** of FIG. **3** may be one configuration of the low noise amplifier (LNA) **228** discussed in connection with FIG. **2**. The first low noise amplifier (LNA) **327** and the second low noise amplifier (LNA) **329** may amplify different bands. For example, the first low noise amplifier (LNA) **327** may serve as a low-frequency low noise amplifier (LNA) and the second low noise amplifier (LNA) **329** may serve as a high-frequency low noise amplifier (LNA). In this example, the low-frequency may be at 800 megahertz (MHz) and the high-frequency may be at 1.99 GHz. In general, frequencies less than 1 GHz are referred to as low-frequency bands and frequencies greater than 1 GHz are referred to as high-frequency bands. For example, the low-frequency band may be at 800 megahertz (MHz) and the high-frequency band may be at 1.99 GHz. In some configurations, additional low noise amplifiers (LNA) may be employed to receive additional input signals and/or provide additional amplified input signals to the multi-port transformer **330**.

The first low noise amplifier (LNA) **327** may output a first amplified input signal **331**. The second low noise amplifier (LNA) **329** may output a second amplified input signal **333**. Both the first amplified input signal **331** and the second amplified input signal **333** may be provided to the multi-port transformer **330**. The multi-port transformer **330** may include a first primary coil (i.e., inductor) L**1** **350***a*, a second primary coil L**2** **350***b* and a secondary coil L**3** **350***c*. The multi-port transformer **330** may also include a center tap **326** that is between the first primary coil L**1** **350***a* and the second primary coil L**2** **350***b*. The center tap **326** may be coupled to a voltage supply (Vdd).

A first coupling may occur between the first primary coil L**1** **350***a* and the second primary coil L**2** **350***b*. The first coupling may have a coupling coefficient of k12. A second coupling may occur between the first primary coil L**1** **350***a* and the secondary coil L**3** **350***c*. The second coupling may have a coupling coefficient of k13. A third coupling may occur between the second primary coil L**2** **350***b* and the secondary coil L**3** **350***c*. The third coupling may have a coupling coefficient of k23. In other words, the mutually coupled coils/inductors L**1** **350***a*, L**2** **350***b* and L**3** **350***c* may couple each other (with coupling coefficients k12, k13 and k23).

The output of the first low noise amplifier (LNA) **327** may be coupled to the first primary coil L**1** **350***a*. The output of the second low noise amplifier (LNA) **329** may be coupled to the second primary coil L**2** **350***b*. The secondary coil L**3** **350***c* may be coupled between a first input **358** of a shared mixer **332** and a second input **360** of the shared mixer **332**. The first input **358** of the shared mixer **332** and a second input **360** of the shared mixer **332** may be 180 degrees out-of-phase with each other.

In one configuration, either the first input signal **316** or the second input signal **318** is active. If the first input signal **316** is active (and thus the second input signal **318** is inactive), the multi-port transformer **330** may provide a differential signal **357** of the first input signal **316** to the shared mixer **332**. Likewise, if the second input signal **318** is active (and thus the first input signal **316** is inactive), the multi-port transformer **330** may provide a differential signal **357** of the second input signal **318** to the shared mixer **332**.

As a result of the multi-port transformer **330**, only a single shared mixer **332** is required in the single-ended receiver **306** to process both the first input signal **316** and the second input signal **318**. As an additional benefit, channel degradation may be reduced and in some cases, eliminated. Furthermore, the single-ended receiver **306** may operate without the use of switches to switch transformers on or off. Because the number of required components is reduced, the single-ended receiver **306** may occupy less die area/printed circuit board area than a differential receiver.

In one configuration, a first capacitor **354** may be coupled between the secondary coil **350***c* and the first input **358** of the shared mixer **332**. Likewise, a second capacitor **356** may be coupled between the secondary coil **350***c* and the second input **360** of the shared mixer **332**. The first capacitor **354** and the second capacitor **356** may tune the differential signal **357** from the multi-port transformer **330** prior to the shared mixer **332**. The tuning may vary according to a tuning factor.

The first capacitor **354** and the second capacitors and **356** may be used in a variety of configurations, so long as they are parallel with the multi-port transformer **330**. For example, the first capacitor **354** may instead be coupled between an output of the first low noise amplifier (LNA) **327** and the first coil L**1** **350***a* and the second capacitor **356** may be coupled between an output of the second low noise amplifier (LNA) **329** and the second coil L**2** **350***b*.

The shared mixer **332** may process the differential signal **357**. The shared mixer **332** may provide the processed signals to a baseband (BB) low pass filter (LPF) **342**. The baseband (BB) low pass filter (LPF) **342** may output a single signal or multiple differential signals. For example, the baseband (BB) low pass filter (LPF) **342** may output a differential I channel signal and a differential Q channel signal. In some cases, the differential I channel signal may include I+ and I− and the differential Q channel signal may include Q+ and Q−. The one or more differential signals output from the baseband (BB) low pass filter (LPF) **342** may be input to an analog-to-digital converter (ADC) **344**. The analog-to-digital converter (ADC) **344** may provide at least one receiver output signal **320**. For example, the analog-to-digital converter (ADC) **344** may provide digital and single-ended signals. The outputs from the analog-to-digital converter (ADC) **344** may represent the I channel and the Q channel.

FIG. **4** is a block diagram illustrating another configuration of a single-ended receiver **406**. The single-ended receiver **406** of FIG. **4** may illustrate one configuration of the single-ended receiver **106** described in connection with FIG. **1**. The single-ended receiver **406** may include a low-frequency low noise amplifier (LNA) **427**, a high-frequency low noise amplifier (LNA) **429**, a multi-port transformer **430**, a shared mixer **432**, a baseband (BB) low pass filter (LPF) **442** and an analog-to-digital converter (ADC) **444**. For simplicity, the single-ended receiver **406** is illustrated with only one channel. However, the channel may include an inphase portion and a quadrature portion.

The multi-port transformer **430** may include a first primary coil (i.e., inductor) L**1** **450***a*, a second primary coil L**2** **450***b* and a secondary coil L**3** **450***c*. The multi-port transformer **430** may also include a center tap **426** that is between the first primary coil L**1** **450***a* and the second primary coil L**2** **450***b*. The center tap **426** may be coupled to a voltage supply (Vdd).

The single-ended receiver **406** may receive a first input signal **416** and/or a second input signal **418**. The first input signal **416** may be amplified by a low-frequency low noise amplifier (LNA) **427**. The low-frequency low noise amplifier (LNA) **427** may output a first amplified input signal **431**. The output of the low-frequency low noise amplifier (LNA) **427** may be coupled to the first primary coil L**1** **450***a*. The first primary coil L**1** **450***a* may thus be coupled between the output of the low-frequency low noise amplifier (LNA) **427** and the center tap **426**.

The second input signal **418** may be amplified by a high-frequency low noise amplifier (LNA) **429**. The high-frequency low noise amplifier (LNA) **429** may output a second amplified input signal **433**. The output of the high-frequency low noise amplifier (LNA) **429** may be coupled to the second primary coil L**2** **450***b*. The second primary coil L**2** **450***b* may thus be coupled between the output of the high-frequency low noise amplifier (LNA) **429** and the center tap **426**.

A first coupling may occur between the first primary coil L**1** **450***a* and the second primary coil L**2** **450***b*. The first coupling may have a coupling coefficient of k12. A second coupling may occur between the first primary coil L**1** **450***a* and the secondary coil L**3** **450***c*. The second coupling may have a coupling coefficient of k13. A third coupling may occur between the second primary coil L**2** **450***b* and the secondary coil L**3** **450***c*. The third coupling may have a coupling coefficient of k23. In other words, the mutually coupled coils/inductors L**1** **450***a*, L**2** **450***b* and L**3** **450***c* may couple each other (with coupling coefficients k12, k13 and k23).

The output of the first low noise amplifier (LNA) **427** may be coupled to the first primary coil L**1** **450***a*. The output of the second low noise amplifier (LNA) **429** may be coupled to the second primary coil L**2** **450***b*. The secondary coil L**3** **450***c* may be coupled between a first input **458** of a shared mixer **432** and a second input **460** of the shared mixer **432**. The first input **458** of the shared mixer **432** and a second input **460** of the shared mixer **432** may be 180 degrees out-of-phase with each other.

In one configuration, either the first input signal **416** or the second input signal **418** is active. If the first input signal **416** is active (and thus the second input signal **418** is inactive), the multi-port transformer **430** may provide a differential signal **457** of the first input signal **416** to the shared mixer **432**. Likewise, if the second input signal **418** is active (and thus the first input signal **416** is inactive), the multi-port transformer **430** may provide a differential signal **457** of the second input signal **418** to the shared mixer **432**.

As a result of the multi-port transformer **430**, only a single shared mixer **432** is required in the single-ended receiver **406** to process both the first input signal **416** and the second input signal **418**. As an additional benefit, channel degradation may be reduced and in some cases, eliminated. Furthermore, the single-ended receiver **406** may operate without the use of switches to switch transformers on or off. Because the number of required components is reduced, the single-ended receiver **406** may occupy less die area/printed circuit board area than a differential receiver.

The shared mixer **432** may downconvert the first shared mixer input signal **458** and the second shared mixer input signal **460** and provide the downconverted signals to the baseband (BB) low pass filter (LPF) **442**. The baseband (BB) low pass filter (LPF) **442** provides the filtered downconverted signals to the analog-to-digital converter (ADC) **444**. The analog-to-digital converter (ADC) may provide at least one receiver output signal **420**.

FIG. **5** is a block diagram illustrating yet another configuration of a single-ended receiver **506**. The single-ended receiver **506** of FIG. **5** may illustrate one configuration of the single-ended receiver **106** described in connection with FIG.

1. For simplicity, the single-ended receiver **506** is illustrated with only one channel. However, the channel may include an inphase portion and a quadrature portion.

The single-ended receiver **506** may include multiple low-frequency low noise amplifiers (LNA) **527***a-b* and multiple a high-frequency low noise amplifiers (LNA) **529***a-b*. For simplicity, only two low-frequency low noise amplifiers (LNA) **527***a-b* and two high-frequency low noise amplifiers (LNA) **529***a-b* are illustrated, but it should be appreciated that more than two low-frequency low noise amplifiers (LNA) **527** and/or more than two high-frequency low noise amplifiers (LNA) **529** may be used. The low-frequency low noise amplifiers (LNA) **527** and high-frequency low noise amplifiers (LNA) **529** may be parallel to each other. For example, low-frequency low noise amplifiers (LNA) **527***a* and low-frequency low noise amplifiers (LNA) **527***b* may be parallel to each other.

A first input signal **516** may be amplified by both first low-frequency low noise amplifiers (LNA) **427***a-b*. The first low-frequency low noise amplifier (LNA) **427***b* may output a first amplified input signal **431**. A second input signal **518** may be amplified by both second low-frequency low noise amplifiers (LNA) **429***a-b*. The second low-frequency low noise amplifier (LNA) **429***b* may output a second amplified input signal **433**.

The single-ended receiver **506** may also include a multi-port transformer **530**, a shared mixer **532**, a baseband (BB) low pass filter (LPF) **542** and an analog-to-digital converter (ADC) **544** similar to corresponding components **430**, **432**, **442** and **444** described in connection with FIG. **4**. For example, the multi-port transformer **530** may include a first primary coil (i.e., inductor) L**1** **550***a*, a second primary coil L**2** **550***b*, a secondary coil L**3** **550***c* and center tap **526** that corresponds to similar elements **450***a*, **450***b*, **450***c* and **426** described in connection with FIG. **4**. In this manner, the first amplified input signal **531** and the second amplified input signal **533** may output a receiver output signal **520** similar to, the first amplified input signal **431** and the second amplified input signal **433** outputting a receiver output signal **420** as described above in FIG. **4**.

FIG. **6** is a flow diagram of a method **600** for receiving a wireless signal using a single-ended receiver **106**. The method **600** may be performed by a wireless device **102**. In one configuration, the method **600** may be performed by a single-ended receiver **106** on the wireless device **102**. The single-ended receiver **106** may receive **602** a first input signal **116**. The single-ended receiver **106** may also receive **604** a second input signal **118**. The first input signal **116** and the second input signal **118** may or may not be received simultaneously. The single-ended receiver **106** may provide **606** a differential signal **357** to a shared mixer **232** from the first input signal **116** or the second input signal **118** using a multi-port transformer **230**.

For example, the multi-port transformer **230** may use the first primary coil L**1** **350***a* coupled to the secondary coil L**3** **350***c* to provide a differential signal **357** from the first input signal **116** to the shared mixer **232**. Likewise, the multi-port transformer **230** may use the second primary coil L**2** **350***b* coupled to the secondary coil L**3** **350***c* to provide a differential signal **357** from the second input signal **118** to the shared mixer **232**.

FIG. **7** is a flow diagram of another method **700** for receiving a wireless signal using a single-ended receiver **106**. The method **700** may be performed by a wireless device **102**. In one configuration, the method **700** may be performed by a single-ended receiver **106** on the wireless device **102**. The single-ended receiver **106** may receive **702** a first input signal **116** that has a first frequency. For example, the first input signal **116** may be a low-frequency input signal.

The single-ended receiver **106** may amplify **704** the first input signal **116** using a low-frequency low noise amplifier (LNA) **327**. The single-ended receiver **106** may provide **706** the first amplified input signal **331** to a first primary coil L**1** **350***a* of a multi-port transformer **230**.

The single-ended receiver **106** may receive **708** a second input signal **118** that has a second frequency. For example, the second input signal **118** may be a high-frequency input signal. Either the first input signal **116** or the second input signal **118** may be provided to the single-ended receiver **106** by a filter/duplexer **114**. The single-ended receiver **106** may amplify **710** the second input signal **118** using a high-frequency low noise amplifier (LNA) **329**.

The single-ended receiver **106** may provide **712** the second amplified input signal **333** to a second primary coil L**2** **350***b* of the multi-port transformer **230**. The single-ended receiver **106** may provide **714** a differential signal **357** from the multi-port transformer **230** to a shared mixer **232**. In one configuration, the differential signal **357** may be a differential signal output from the first input signal **116**. In another configuration, the differential signal **357** may be a differential signal output from the second input signal **118**.

The single-ended receiver **106** may provide **714** the first amplified input signal **331** or the second amplified input signal **333** to the shared mixer **232** as a differential signal **357** by coupling the first primary coil L**1** **350***a* or the second primary coil L**2** **350***b* to a secondary coil L**3** **350***c*. The single-ended receiver **106** may provide **714** the first amplified input signal **331** to the shared mixer **232** by coupling the first primary coil L**1** **350***a* to the secondary coil L**3** **350***c*. Similarly, the single-ended receiver **106** may provide **714** the second amplified input signal **333** to the shared mixer **232** by coupling the second primary coil L**2** **350***b* to a secondary coil L**3** **350***c*.

FIG. **8** is a layout diagram illustrating one configuration **800** of a single-ended receiver **106**. FIG. **8** may illustrate one implementation of the multi-port transformer **230** of FIG. **2**. The single-ended receiver layout may include a first primary coil (i.e., inductor) L**1** **850***a*, a second primary coil L**2** **850***b* and a secondary coil L**3** **850***c*. The first primary coil L**1** **850***a* and the second primary coil L**2** **850***b* may be the same type or different types of inductors. The first primary coil L**1** **850***a* may receive input from a first amplified input signal **831**. The second primary coil L**2** **850***b* may receive input from a second amplified input signal **833**. The secondary coil L**3** **850***c* may output a produce a differential signal **857**. The single-ended receiver layout may also include a center tap **826** that is between the first primary coil L**1** **850***a* and the second primary coil L**2** **850***b*. The center tap **826** may be coupled to a voltage supply (V_{DD}).

FIG. **9** illustrates certain components that may be included within a base station **902**. A base station **902** may also be referred to as, and may include some or all of the functionality of, an access point, a broadcast transmitter, a node B, an evolved node B, etc. For example, the base station **902** may be the wireless device **102** of FIG. **1**. The base station **902** may include a processor **903**. The processor **903** may be a general purpose single- or multi-chip microprocessor (e.g., an ARM), a special purpose microprocessor (e.g., a digital signal processor (DSP)), a microcontroller, a programmable gate array, etc. The processor **903** may be referred to as a central processing unit (CPU). Although just a single processor **903** is shown in the base station **902** of FIG. **9**, in an alternative configuration, a combination of processors (e.g., an ARM and DSP) could be used.

The base station **902** also includes memory **905**. The memory **905** may be any electronic component capable of storing electronic information. The memory **905** may be embodied as random access memory (RAM), read only memory (ROM), magnetic disk storage media, optical storage media, flash memory devices in RAM, on-board memory included with the processor, EPROM memory, EEPROM memory, registers and so forth, including combinations thereof.

Data **907***a* and instructions **909***a* may be stored in the memory **905**. The instructions **909***a* may be executable by the processor **903** to implement the methods disclosed herein. Executing the instructions **909***a* may involve the use of the data **907***a* that is stored in the memory **905**. When the processor **903** executes the instructions **909***a*, various portions of the instructions **909***b* may be loaded onto the processor **903**, and various pieces of data **907***b* may be loaded onto the processor **903**.

The base station **902** may also include a transmitter **911** and a receiver **913** to allow transmission and reception of signals to and from the base station **902**. The transmitter **911** and receiver **913** may be collectively referred to as a transceiver **915**. The receiver **913** of FIG. **9** may be one configuration of the receiver **104** illustrated in FIG. **1** and/or the receiver **204** illustrated in FIG. **2**. An antenna **917** may be electrically coupled to the transceiver **915**.

The base station **902** may include a Digital Signal Processor (DSP) **921**. The base station **902** may also include a communications interface **923**. The communications interface **923** may allow a user to interact with the base station **902**.

The various components of the base station **902** may be coupled together by one or more buses, which may include a power bus, a control signal bus, a status signal bus, a data bus, etc. For the sake of clarity, the various buses are illustrated in FIG. **9** as a bus system **919**.

FIG. **10** illustrates certain components that may be included within a wireless device **1002**. The wireless device **1002** may be an access terminal, a mobile station, a user equipment (UE), etc. For example, the wireless device **1002** may be the wireless device **102** of FIG. **1**. Additionally or alternatively, the wireless device **1002** may include the receiver **104** illustrated in FIG. **1** and/or the receiver **204** illustrated in FIG. **2**. The wireless device **1002** includes a processor **1003**. The processor **1003** may be a general purpose single- or multi-chip microprocessor (e.g., an ARM), a special purpose microprocessor (e.g., a DSP), a microcontroller, a programmable gate array, etc. The processor **1003** may be referred to as a central processing unit (CPU). Although just a single processor **1003** is shown in the wireless device **1002** of FIG. **10**, in an alternative configuration, a combination of processors (e.g., an ARM and DSP) could be used.

The wireless device **1002** also includes memory **1005**. The memory **1005** may be any electronic component capable of storing electronic information. The memory **1005** may be embodied as random access memory (RAM), read-only memory (ROM), magnetic disk storage media, optical storage media, flash memory devices in RAM, on-board memory included with the processor, EPROM memory, EEPROM memory, registers, and so forth, including combinations thereof.

Data **1007***a* and instructions **1009***a* may be stored in the memory **1005**. The instructions **1009***a* may be executable by the processor **1003** to implement the methods disclosed herein. Executing the instructions **1009***a* may involve the use of the data **1007***a* that is stored in the memory **1005**.

When the processor **1003** executes the instructions **1009***a*, various portions of the instructions **1009***b* may be loaded onto the processor **1003**, and various pieces of data **1007***b* may be loaded onto the processor **1003**.

The wireless device **1002** may also include a transmitter **1011** and a receiver **1013** to allow transmission and reception of signals to and from the wireless device **1002**. The transmitter **1011** and receiver **1013** may be collectively referred to as a transceiver **1015**. An antenna **1017** may be electrically coupled to the transceiver **1015**.

The wireless device **1002** may include a Digital Signal Processor (DSP) **1021**. The wireless device **1002** may also include a communications interface **1023**. The communications interface **1023** may allow a user to interact with the wireless device **1002**.

The various components of the wireless device **1002** may be coupled together by one or more buses, which may include a power bus, a control signal bus, a status signal bus, a data bus, etc. For the sake of clarity, the various buses are illustrated in FIG. **10** as a bus system **1019**.

The term “determining” encompasses a wide variety of actions and, therefore, “determining” can include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, “determining” can include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, “determining” can include resolving, selecting, choosing, establishing and the like.

The phrase “based on” does not mean “based only on,” unless expressly specified otherwise. In other words, the phrase “based on” describes both “based only on” and “based at least on.”

The term “processor” should be interpreted broadly to encompass a general purpose processor, a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a controller, a microcontroller, a state machine and so forth. Under some circumstances, a “processor” may refer to an application specific integrated circuit (ASIC), a programmable logic device (PLD), a field programmable gate array (FPGA), etc. The term “processor” may refer to a combination of processing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The term “memory” should be interpreted broadly to encompass any electronic component capable of storing electronic information. The term memory may refer to various types of processor-readable media such as random access memory (RAM), read-only memory (ROM), non-volatile random access memory (NVRAM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable PROM (EEPROM), flash memory, magnetic or optical data storage, registers, etc. Memory is said to be in electronic communication with a processor if the processor can read information from and/or write information to the memory. Memory that is integral to a processor is in electronic communication with the processor.

The terms “instructions” and “code” should be interpreted broadly to include any type of computer-readable statement(s). For example, the terms “instructions” and “code” may refer to one or more programs, routines, subroutines, functions, procedures, etc. “Instructions” and “code” may comprise a single computer-readable statement or many computer-readable statements.

The functions described herein may be stored as one or more instructions on a processor-readable or computer-readable medium. The term "computer-readable medium" refers to any available medium that can be accessed by a computer or processor. By way of example, and not limitation, such a medium may comprise RAM, ROM, EEPROM, flash memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to store desired program code in the form of instructions or data structures and that can be accessed by a computer or processor. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. It should be noted that a computer-readable medium may be tangible and non-transitory. The term "computer-program product" refers to a computing device or processor in combination with code or instructions (e.g., a "program") that may be executed, processed or computed by the computing device or processor. As used herein, the term "code" may refer to software, instructions, code or data that is/are executable by a computing device or processor.

Software or instructions may also be transmitted over a transmission medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio and microwave are included in the definition of transmission medium.

The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein, such as those illustrated by FIGS. **5** and **6**, can be downloaded and/or otherwise obtained by a device. For example, a device may be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via a storage means (e.g., random access memory (RAM), read-only memory (ROM), a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a device may obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods and apparatus described herein without departing from the scope of the claims.

What is claimed is:

1. A single-ended receiver, comprising:

a multi-port transformer that outputs a differential signal, the multi-port transformer comprising:

a first primary coil that is coupled to an output of a first low noise amplifier;

a second primary coil that is distinct from the first primary coil and that is coupled to an output of a second low noise amplifier; and

a first secondary coil; and

a shared mixer that receives the differential signal from the multi-port transformer.

2. The single-ended receiver of claim **1**, wherein the multi-port transformer further comprises:

a first coupling between the first primary coil and the second primary coil;

a second coupling between the first primary coil and the first secondary coil; and

a third coupling between the second primary coil and the first secondary coil.

3. The single-ended receiver of claim **1**, wherein the first low noise amplifier receives a first input signal and wherein the second low noise amplifier receives a second input signal.

4. The single-ended receiver of claim **3**, wherein the first input signal is active and the second input signal is inactive and wherein the multi-port transformer outputs the differential signal based on the first input signal.

5. The single-ended receiver of claim **3**, wherein the first input signal is inactive and the second input signal is active and wherein the multi-port transformer outputs the differential signal based on the second input signal.

6. The single-ended receiver of claim **3**, wherein the first input signal has a first frequency and the second input signal has a second frequency.

7. The single-ended receiver of claim **1**, wherein the multi-port transformer further comprises a center tap between the first primary coil and the second primary coil, and wherein the center tap is coupled to a voltage supply.

8. The single-ended receiver of claim **1**, wherein the first low noise amplifier comprises a low-frequency low noise amplifier for operation with a low-frequency signal, and wherein the second low noise amplifier comprises a high-frequency low noise amplifier for operation with a high-frequency signal.

9. The single-ended receiver of claim **8**, wherein the first low noise amplifier receives a low-frequency input signal, and wherein the second low noise amplifier receives a high-frequency second signal.

10. The single-ended receiver of claim **1**, further comprising a baseband low pass filter coupled to the shared mixer.

11. The single-ended receiver of claim **10**, further comprising an analog-to-digital converter coupled to the baseband low pass filter, wherein the baseband low pass filter outputs a receiver output signal.

12. The single-ended receiver of claim **1**, wherein the first secondary coil is coupled to a first shared mixer input and a second shared mixer input of the shared mixer.

13. The single-ended receiver of claim **12**, further comprising:

a first capacitor that couples the first secondary coil to the first shared mixer input; and

a second capacitor that couples the first secondary coil to the second shared mixer input.

14. The single-ended receiver of claim **1**, further comprising an additional first low noise amplifier in parallel with the first low noise amplifier and an additional second low noise amplifier parallel with the second low noise amplifier.

15. The single-ended receiver of claim **14**, wherein the additional first low noise amplifier receives a first input signal, and wherein the additional second low noise amplifier receives a second input signal.

16. The single-ended receiver of claim **15**, wherein the first input signal has a first frequency and the second input signal has a second frequency.

17. A method for receiving a wireless signal, the method comprising:

receiving a first input signal;

receiving a second input signal; and

providing a differential signal to a shared mixer from one of the first input signal and the second input signal using a multi-port transformer comprising a first primary coil, a second primary coil that is distinct from the first primary coil, and a first secondary coil.

18. The method of claim **17**, further comprising amplifying the first input signal using a first low noise amplifier.

19. The method of claim **18**, wherein the first low noise amplifier comprises a low-frequency low noise amplifier for operation with a low-frequency signal.

20. The method of claim **17**, further comprising amplifying the second input signal using a second low noise amplifier.

21. The method of claim **20**, wherein the second low noise amplifier comprises a high-frequency low noise amplifier for operation with a high-frequency signal.

22. The method of claim **17**, wherein the first input signal has a first frequency and the second input signal has a second frequency.

23. The method of claim **17**, wherein a first low noise amplifier receives the first input signal and a second low noise amplifier receives the second input signal.

24. The method of claim **23**, wherein the first input signal is active and the second input signal is inactive, and wherein the multi-port transformer outputs the differential signal based on the first input signal.

25. The method of claim **23**, wherein the first input signal is inactive and the second input signal is active and wherein the multi-port transformer outputs the differential signal based on the second input signal.

26. The method of claim **17**, wherein:

the first primary coil is coupled to an output of a first low noise amplifier; and

the second primary coil is coupled to an output of a second low noise amplifier.

27. The method of claim **26**, wherein the multi-port transformer further comprises a center tap between the first primary coil and the second primary coil.

28. The method of claim **26**, wherein the multi-port transformer further comprises:

a first coupling between the first primary coil and the second primary coil;

a second coupling between the first primary coil and the first secondary coil; and

a third coupling between the second primary coil and the first secondary coil.

29. The method of claim **28**, wherein the first secondary coil is coupled to a first shared mixer input and a second shared mixer input of the shared mixer.

30. The method of claim **17**, wherein the method is performed by a single-ended receiver on a wireless device, and wherein the single-ended receiver comprises the shared mixer and the multi-port transformer.

31. The method of claim **30**, wherein the single-ended receiver further comprises a baseband low pass filter coupled to the shared mixer.

32. The method of claim **31**, wherein the single-ended receiver further comprises an analog-to-digital converter coupled to the baseband low pass filter, and wherein the baseband low pass filter outputs a receiver output signal.

33. The method of claim **30**, wherein the single-ended receiver further comprises:

a first capacitor coupled between the first secondary coil and the first shared mixer input; and

a second capacitor coupled between the first secondary coil and the second shared mixer input.

34. The method of claim **17**, wherein the multi-port transformer further comprises an additional first low noise amplifier parallel with the first low noise amplifier and an additional second low noise amplifier parallel with the second low noise amplifier.

35. The method of claim **34**, further comprising, wherein the additional first low noise amplifier receives the first input signal, and wherein the additional second low noise amplifier receives the second input signal.

36. The method of claim **35**, wherein the first input signal has a first frequency and the second input signal has a second frequency.

37. An apparatus, comprising:

means for receiving a first input signal;

means for receiving a second input signal; and

means for providing a differential signal to a shared mixer from one of the first input signal and the second input signal using a multi-port transformer comprising a first primary coil, a second primary coil that is distinct from the first primary coil, and a first secondary coil.

38. The apparatus of claim **37**, wherein:

the first primary coil is coupled to an output of a first low noise amplifier; and

the second primary coil is coupled to an output of a second low noise amplifier.

39. The apparatus of claim **38**, wherein the multi-port transformer further comprises:

a first coupling between the first primary coil and the second primary coil;

a second coupling between the first primary coil and the first secondary coil; and

a third coupling between the second primary coil and the first secondary coil.

40. A computer-program product for receiving a wireless signal, the computer-program product comprising a non-transitory computer-readable medium having instructions thereon, the instructions comprising:

code for causing a wireless device to receive a first input signal;

code for causing the wireless device to receive a second input signal; and

code for causing the wireless device to provide a differential signal to a shared mixer from one of the first input signal and the second input signal using a multi-port transformer comprising a first primary coil, a second primary coil that is distinct from the first primary coil, and a first secondary coil.

41. The computer-program product of claim **40**, wherein:

the first primary coil is coupled to an output of a first low noise amplifier; and

the second primary coil is coupled to an output of a second low noise amplifier.

42. The computer-program product of claim **41**, wherein the multi-port transformer further comprises:

a first coupling between the first primary coil and the second primary coil;

a second coupling between the first primary coil and the first secondary coil; and

a third coupling between the second primary coil and the first secondary coil.

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