



US009172402B2

(12) **United States Patent**  
**Gudem et al.**

(10) **Patent No.:** **US 9,172,402 B2**  
(45) **Date of Patent:** **Oct. 27, 2015**

(54) **MULTIPLE-INPUT AND MULTIPLE-OUTPUT CARRIER AGGREGATION RECEIVER REUSE ARCHITECTURE**

(75) Inventors: **Prasad Srinivasa Siva Gudem**, San Diego, CA (US); **Xiaoyin He**, San Diego, CA (US); **Tamer Adel Kadous**, San Diego, CA (US); **Li-Chung Chang**, Irvine, CA (US)

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

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/411,467**

(22) Filed: **Mar. 2, 2012**

(65) **Prior Publication Data**

US 2013/0230080 A1 Sep. 5, 2013

(51) **Int. Cl.**  
**H04B 1/00** (2006.01)  
**H04B 1/525** (2015.01)  
**H04B 7/04** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H04B 1/0057** (2013.01); **H04B 1/0064** (2013.01); **H04B 1/525** (2013.01); **H04B 7/0413** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H04B 7/0413; H04B 1/0057; H04B 1/38; H04L 5/001; H04W 72/04  
USPC ..... 375/219, 260, 267, 295, 299, 316, 347, 375/340; 455/101, 132, 500, 562.1; 370/334, 464, 480

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,911,364 A 10/1975 Langseth et al.  
4,035,728 A 7/1977 Ishikawa et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1523912 A 8/2004  
CN 1922795 A 2/2007

(Continued)

OTHER PUBLICATIONS

Aparin et al., "A Highly-integrated tri-band/quad-mode SiGe BiCMOS RF-to-baseband and receiver for wireless CDMA/WCDMA/AMPS applications with GPS capability", Solid-State Circuits Conference, 2002. Digest of Technical Papers. 2002 IEEE International Feb. 3-7, 2002, Piscataway, NJ, USA, IEEE, vol. 1, 2002, pp. 234-235, XP010585547, ISBN: 0-7803-7335-9.

(Continued)

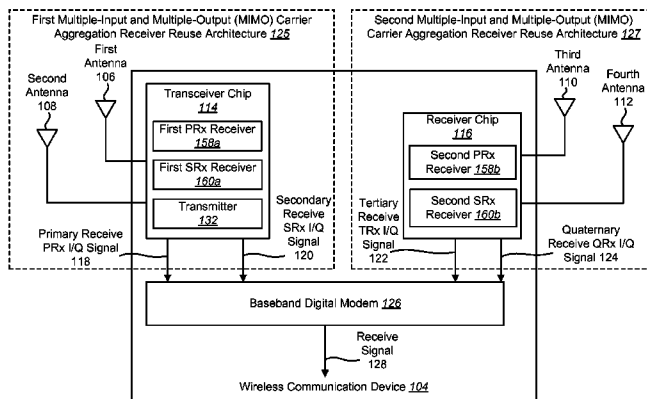
*Primary Examiner* — Leon Flores

(74) *Attorney, Agent, or Firm* — James Gutierrez

(57) **ABSTRACT**

A wireless communication device configured for receiving a wireless multiple-input and multiple-output signal. The wireless communication device includes a first multiple-input and multiple-output carrier aggregation receiver reuse architecture. The first multiple-input and multiple-output carrier aggregation receiver reuse architecture includes a first antenna, a second antenna and a transceiver chip. The first multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a first carrier aggregation receiver reuse architecture. The wireless communication device also includes a second multiple-input and multiple-output carrier aggregation receiver reuse architecture. The second multiple-input and multiple-output carrier aggregation receiver reuse architecture includes a third antenna, a fourth antenna and a receiver chip. The second multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a second carrier aggregation receiver reuse path.

**31 Claims, 9 Drawing Sheets**



(56)

## References Cited

## U.S. PATENT DOCUMENTS

4,035,729 A	7/1977	Perry	7,454,181 B2	11/2008	Banister et al.
4,246,655 A	1/1981	Parker	7,477,106 B2	1/2009	Van Bezooijen et al.
4,326,294 A	4/1982	Okamoto et al.	7,486,135 B2	2/2009	Mu
4,715,048 A	12/1987	Masamura	7,570,111 B1	8/2009	Vagher et al.
4,742,563 A	5/1988	Fukumura	7,599,675 B2	10/2009	Mu et al.
4,756,023 A	7/1988	Kojima	7,643,847 B2	1/2010	Daanen et al.
4,969,207 A	11/1990	Sakamoto et al.	7,643,848 B2	1/2010	Robinett
5,056,411 A	10/1991	Baker	7,697,905 B2	4/2010	Lee et al.
5,128,630 A	7/1992	Mijuskovic	7,728,664 B2	6/2010	Chang et al.
5,291,519 A	3/1994	Tsurumaru	7,751,513 B2	7/2010	Eisenhut et al.
5,321,850 A	6/1994	Backstrom et al.	7,764,726 B2	7/2010	Simic et al.
5,345,601 A	9/1994	Takagi et al.	7,848,724 B2	12/2010	Bult et al.
5,390,342 A	2/1995	Takayama et al.	7,869,528 B2	1/2011	Robinson
5,559,838 A	9/1996	Nakagoshi	7,877,075 B1	1/2011	Jin et al.
5,566,364 A	10/1996	Mizoguchi et al.	7,911,269 B2	3/2011	Yang et al.
5,694,396 A	12/1997	Firouzbakht et al.	7,944,298 B2	5/2011	Cabanillas et al.
5,697,083 A	12/1997	Sano	7,949,309 B2	5/2011	Rofougaran et al.
5,761,613 A	6/1998	Saunders et al.	7,952,398 B2	5/2011	Salcido et al.
5,794,159 A	8/1998	Portin	8,022,772 B2	9/2011	Cassia et al.
5,805,643 A	9/1998	Seki et al.	8,055,229 B2	11/2011	Huang
5,805,989 A	9/1998	Ushida	8,063,706 B2	11/2011	Li et al.
5,835,853 A	11/1998	Enoki et al.	8,081,672 B2	12/2011	Kent et al.
5,940,452 A	8/1999	Rich	8,090,332 B2	1/2012	Sahota et al.
5,999,815 A	12/1999	Tenbrook et al.	8,090,369 B2	1/2012	Kitazoe
5,999,990 A	12/1999	Sharrit et al.	8,139,670 B1*	3/2012	Son et al. .... 375/267
6,026,288 A	2/2000	Bronner	8,149,955 B2	4/2012	Tired
6,040,732 A	3/2000	Brokaw	8,195,117 B2	6/2012	Bult et al.
6,044,254 A	3/2000	Ohta et al.	8,208,887 B2	6/2012	Lee et al.
6,063,961 A	5/2000	Kroner	8,217,723 B2	7/2012	Rajendran et al.
6,069,923 A	5/2000	Ostman et al.	8,242,841 B2	8/2012	Zhang
6,088,348 A	7/2000	Bell, III et al.	8,270,927 B2	9/2012	Wallace et al.
6,208,844 B1	3/2001	Abdelgany	8,290,449 B2	10/2012	Keehr et al.
6,249,687 B1	6/2001	Thomsen et al.	8,295,778 B2	10/2012	Kotecha et al.
6,407,689 B1	6/2002	Bazarjani et al.	8,306,494 B2	11/2012	Ojo
6,424,683 B1	7/2002	Schoellhorn	8,442,473 B1	5/2013	Kaukovuori et al.
6,430,237 B1	8/2002	Anvari	8,514,015 B2	8/2013	Chen
6,472,947 B1	10/2002	Zeitz	8,571,510 B2	10/2013	Liu et al.
6,473,601 B1	10/2002	Oda	8,600,315 B2	12/2013	Roufoogaran et al.
6,522,895 B1	2/2003	Montalvo	8,626,084 B2	1/2014	Chan et al.
6,535,725 B2	3/2003	Hatcher et al.	8,676,148 B2	3/2014	Ogasawara
6,600,759 B1	7/2003	Wood	8,706,069 B2	4/2014	Khoini-Poorfard et al.
6,600,907 B1	7/2003	Taguchi	2002/0008575 A1	1/2002	Oskowsky et al.
6,600,931 B2	7/2003	Sutton et al.	2002/0061773 A1	5/2002	Adachi et al.
6,657,498 B2	12/2003	Park et al.	2002/0111163 A1	8/2002	Hamabe
6,806,777 B2	10/2004	Franca-Neto	2002/0132597 A1	9/2002	Peterzell et al.
6,819,941 B2	11/2004	Dening et al.	2002/0173337 A1	11/2002	Hajimiri et al.
6,888,888 B1	5/2005	Tu et al.	2002/0193108 A1	12/2002	Robinett
6,952,594 B2	10/2005	Hendin	2003/0076797 A1	4/2003	Lozano
6,954,446 B2	10/2005	Kuffner	2003/0081694 A1	5/2003	Wieck
6,983,132 B2	1/2006	Woo et al.	2003/0125040 A1	7/2003	Walton et al.
6,985,712 B2	1/2006	Yamakawa et al.	2003/0148750 A1	8/2003	Yan et al.
6,987,950 B2	1/2006	Coan	2003/0157915 A1	8/2003	Atkinson et al.
7,013,166 B2	3/2006	Clifford	2003/0176176 A1	9/2003	Leinonen et al.
7,023,272 B2	4/2006	Hung et al.	2003/0203743 A1	10/2003	Sugar et al.
7,024,172 B1	4/2006	Murphy et al.	2003/0206076 A1	11/2003	Hashemi et al.
7,039,377 B2	5/2006	Yates	2003/0228851 A1	12/2003	Taniguchi
7,123,891 B2	10/2006	Loke	2004/0087290 A1	5/2004	Schmidt et al.
7,142,042 B1	11/2006	Henry	2004/0092243 A1	5/2004	Hey-Shipton
7,161,423 B2	1/2007	Paul et al.	2004/0113746 A1	6/2004	Brindle
7,167,044 B2	1/2007	Zhenbiao et al.	2004/0116086 A1	6/2004	Huttunen
7,187,239 B2	3/2007	Yeh	2004/0121753 A1	6/2004	Sugar et al.
7,187,735 B2	3/2007	Kent, III	2004/0204104 A1	10/2004	Horng et al.
7,187,904 B2	3/2007	Gainey et al.	2004/0219959 A1	11/2004	Khayrallah et al.
7,212,788 B2	5/2007	Weber et al.	2004/0224643 A1	11/2004	Nakai
7,224,231 B2	5/2007	Wu	2004/0253955 A1	12/2004	Love et al.
7,260,377 B2	8/2007	Burns et al.	2004/0266356 A1	12/2004	Javor et al.
7,283,851 B2	10/2007	Persico et al.	2005/0039060 A1	2/2005	Okayasu
7,299,021 B2	11/2007	Pärssinen et al.	2005/0075077 A1	4/2005	Mach et al.
7,313,368 B2	12/2007	Wu et al.	2005/0079847 A1	4/2005	Arafa
7,317,894 B2	1/2008	Hirose	2005/0118977 A1	6/2005	Drogi et al.
7,333,831 B2	2/2008	Srinivasan et al.	2005/0197090 A1	9/2005	Stockstad et al.
7,356,325 B2*	4/2008	Behzad et al. .... 455/323	2005/0215264 A1	9/2005	Subramaniam et al.
7,372,336 B2	5/2008	Lee et al.	2005/0265084 A1	12/2005	Choi
7,403,508 B1	7/2008	Miao	2005/0277387 A1	12/2005	Kojima et al.
7,444,166 B2	10/2008	Sahota	2006/0009177 A1	1/2006	Persico et al.
			2006/0023745 A1	2/2006	Koo et al.
			2006/0061773 A1	3/2006	Lee et al.
			2006/0121937 A1	6/2006	Son
			2006/0128322 A1	6/2006	Igarashi et al.



(56)

## References Cited

## FOREIGN PATENT DOCUMENTS

WO	WO2005064816	A1	7/2005
WO	2005088847	A1	9/2005
WO	2006050515	A2	5/2006
WO	2006118538	A2	11/2006
WO	2008059257	A1	5/2008
WO	2008084539	A1	7/2008
WO	08103757		8/2008
WO	2008092745	A1	8/2008
WO	2008145604	A1	12/2008
WO	2010059257	A1	5/2010
WO	2011019850	A1	2/2011
WO	2011050729	A1	5/2011
WO	2011092005	A1	8/2011
WO	2011138697	A1	11/2011
WO	2012008705	A2	1/2012
WO	2012049529	A1	4/2012
WO	2012158976	A1	11/2012
WO	2013036794	A1	3/2013
WO	2013131047		9/2013

## OTHER PUBLICATIONS

Hwang, et al., "A High IIP2 Direct-Conversion Receiver using Even-Harmonic Reduction Technique for Cellular CDMA/PCS/GPS applications," IEEE Transaction on Circuits and Systems.

MSM6000 Chipset Solution, Qualcomm Incorporated.

MSM6500 Chipset Solution, Qualcomm Incorporated.

Sever et al. "A Dual-Antenna Phase-Array Ultra-Wideband CMOS Transceiver". IEEE Communications Magazine [Online] 2006, vol. 44, Issue 8, pp. 102-110. See pp. 104-107.

Winternitz, et al., "A GPS Receiver for High-Altitude Satellite Navigation," IEEE Journal of Selected Topics in Signal Processing, vol. 3, No. 4, pp. 541-556, Aug. 2009.

3GPP TS 36.101 V11.0.0, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 11), Mar. 2012.

Broyde F., et al., "The Noise Performance of a Multiple-Input-Port and Multiple-Output-Port Low-Noise Amplifier Connected to an Array of Coupled Antennas," International Journal of Antennas and Propagation, vol. 2011, Article ID 438478, Jul. 18, 2011, 12 pages.

Chen, et al., "A 5-6 GHz 1-V CMOS Direct-Conversion Receiver With an Integrated Quadrature Coupler," IEEE Journal of Solid-State Circuits, vol. 42, No. 9, 2007, pp. 1963-1975.

Chen, et al., "A monolithic 5.9-GHz CMOS I/Q direct-down converter utilizing a quadrature coupler and transformer-coupled subharmonic mixers," Microwave and Wireless Components Letters, IEEE, vol. 16, No. 4, 2006, pp. 197-199.

Garuda, et al., "A Multi-band CMOS RF Front-end for 4G WiMAX and WLAN Applications," 2006 IEEE International Symposium on Circuits and Systems, 2006. ISCAS 2006. May 2006, 4 pages.

Hashemi, et al., "Concurrent Multiband Low-Noise Amplifiers—Theory, Design, and Applications," IEEE Transactions on Microwave Theory and Techniques, vol. 50, No. 1, Jan. 2002.

Henrik M et al., "A Full Duplex Front End Module for WiFi 802.11.n Applications", European Microwave Association, vol. 12, No. 4, Oct. 2008, pp. 162-165.

International Search Report and Written Opinion—PCT/US2013/028737—ISA/EPO—Jul. 5, 2013.

Jones W. W., et al., "Narrowband interference suppression using filter-bank analysis/synthesis techniques", Military Communications Conference, 1992. Milcom '92, Conference Record. Communications—Fusing Command, Control and Intelligence., IEEE San Diego, CA, USA, 11-14 Oct. 1992, New York, NY, USA, IEEE, US, Oct. 11, 1992, pp. 898-902, XP010060840, DOI: 10.1109/MILCOM.1992.243977, ISBN: 978-0-7803-0585-4.

Jussi R et al., "A Dual-Band RF Front-End for WCDMA and GSM Applications", IEEE, Journal Solid-State Circuits, 2001, vol. 36, No. 8, pp. 1198-1204.

Kevin W et al., "3G/4G Multimode Cellular Front End Challenges", Part 2: Architecture Discussion, RFMD® White Paper, 9 pages.

Kim, T.W., et al., Highly Linear Receiver Front-End Adopting MOSFET Transconductance Linearization by Multiple Gated Transistors, IEEE Journal of Solid-State Circuits, United States, IEEE, Jan. 1, 2004, vol. 39, No. 1, pp. 223-229.

Lai, C.M., et al., "Compact router transceiver architecture for carrier aggregation systems", Microwave Conference (EUMC), 2011 41st European, IEEE, Oct. 10, 2011, pp. 693-696, XP032072825, ISBN: 978-1-61284-235-6 the whole document.

Lee et al., "Development of Miniature Quad SAW filter bank based on PCB substrate", IEEE Intl Frequency Control Symp, pp. 146-149, 2007.

Pitschi M. et al., "High Performance Microwave Acoustic Components for Mobile Radios", Ultrasonics Symposium (IUS), 2009 IEEE International, EPCOS AG, Munich, Germany, vol. 1, Sep. 20-23, 2009.

Qualcomm Europe: "UE Implementation Impact due to 4C-HSDPA Operation", 3GPP Draft; R1-094067\_UE\_IMPL\_IMPACT\_4C\_HSDPA, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, No. Miyazaki; Oct. 12, 2009, XP050388547, [retrieved on Oct. 6, 2009].

Rahn D.G., et al., "A fully integrated multiband MIMO WLAN transceiver RFIC," IEEE J. Solid-State Circuits, 2005, vol. 40 (8), 1629-1641.

Tasic A. et al., "Design of Adaptive Multimode RF Front-End Circuits", IEEE Journal of Solid-State Circuits, vol. 42, Issue 2, Feb. 2007 pp. 313-322.

"UMTS Picocell Front End Module", CTS Corp. 8 pages.

Philips: "Capabilities of multi-transceiver UES", 3GPP Draft; R1-103913, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, vol. RAN WG1, No. Dresden, Germany; 20100628, Jun. 22, 2010, XP050449298, [retrieved on Jun. 22, 2010] the whole document.

\* cited by examiner

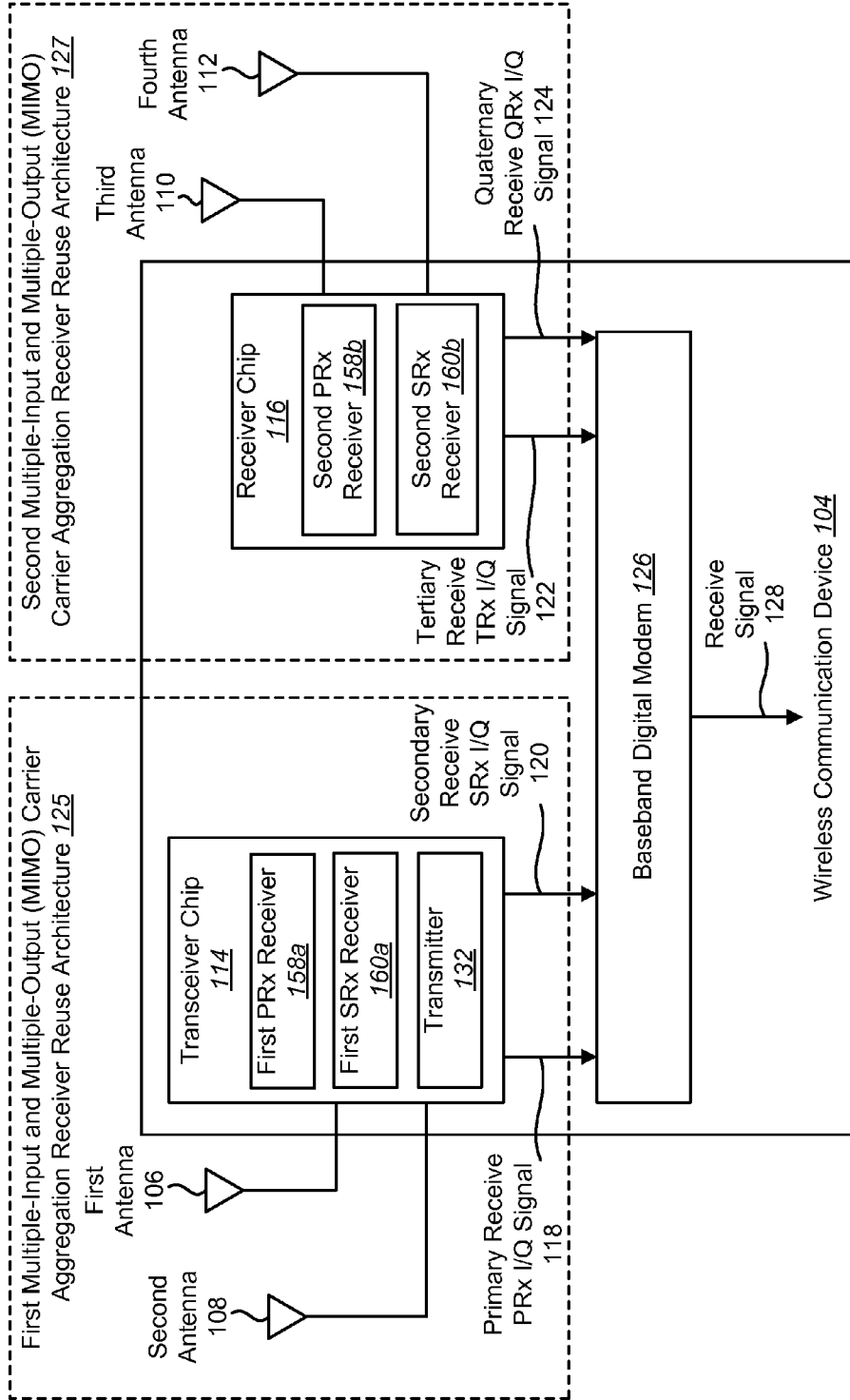


FIG. 1

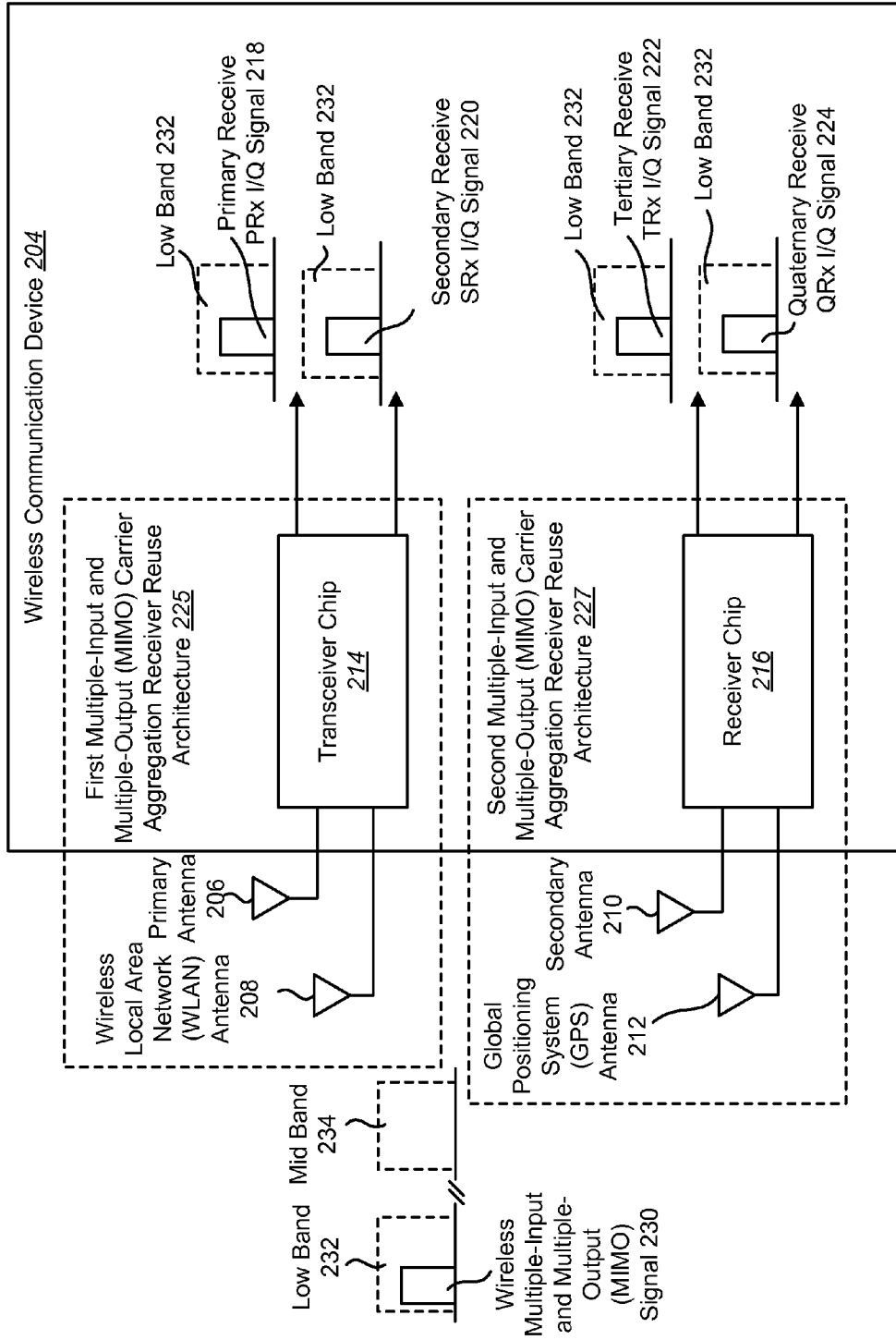
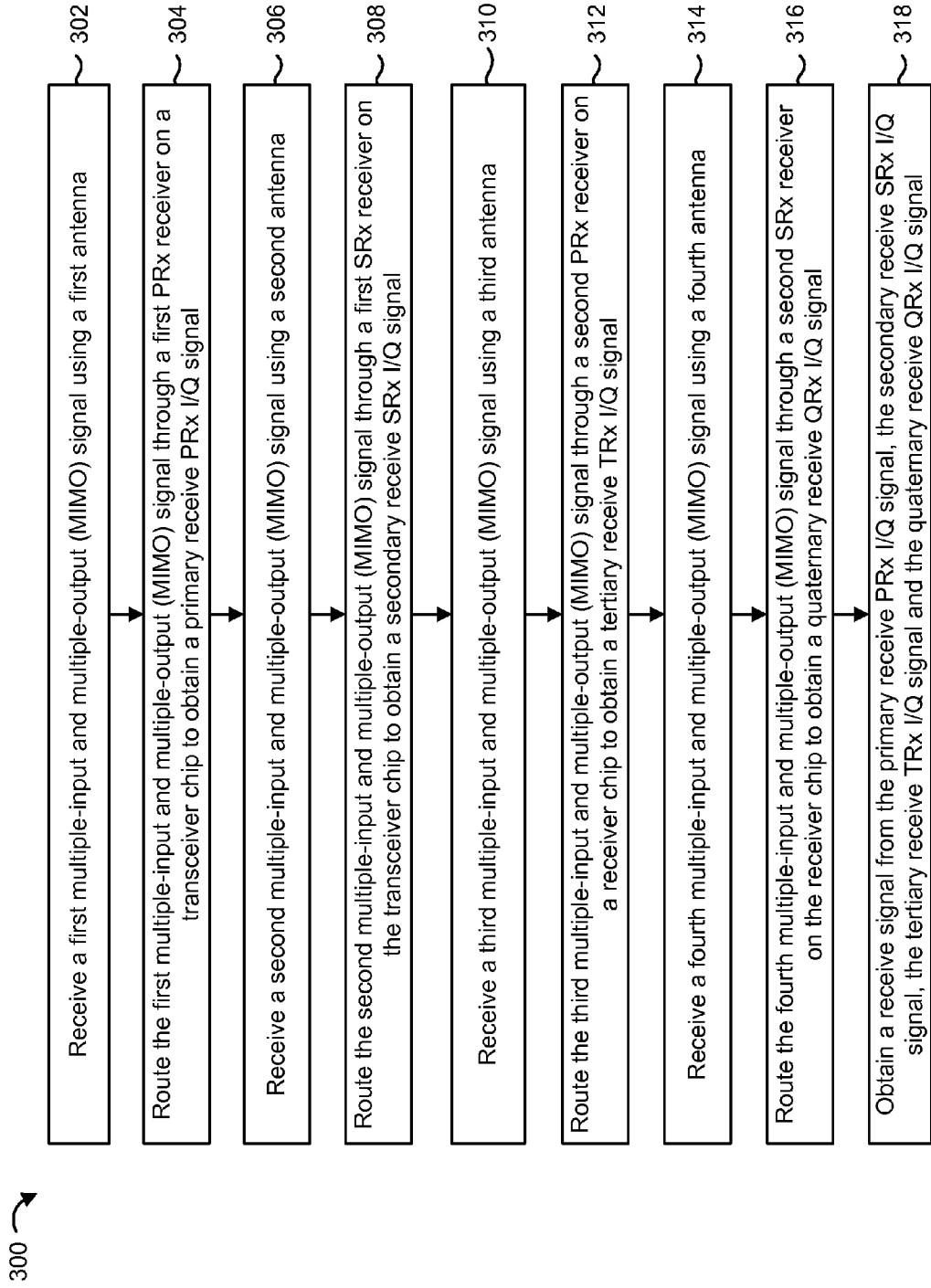


FIG. 2



**FIG. 3**

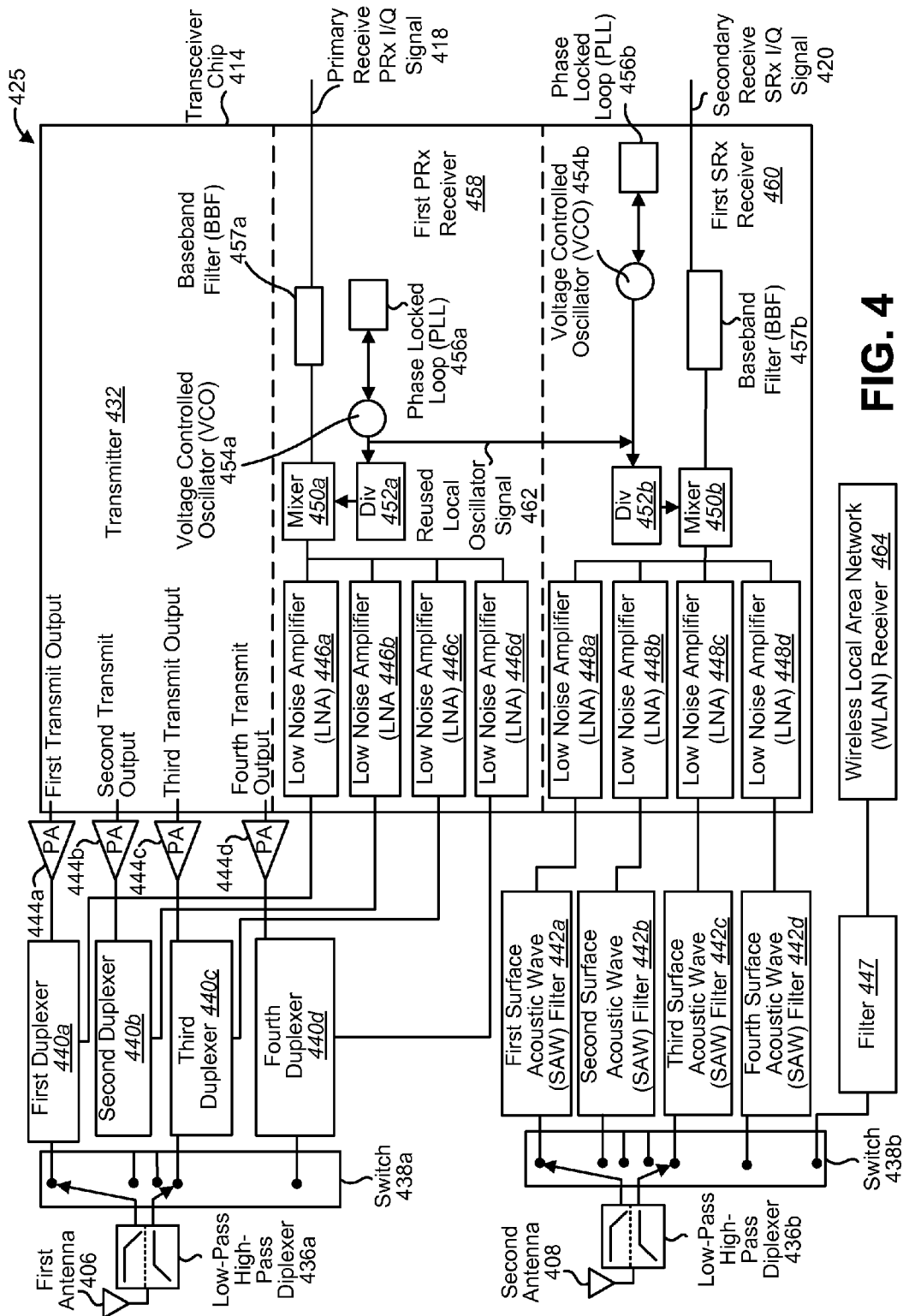
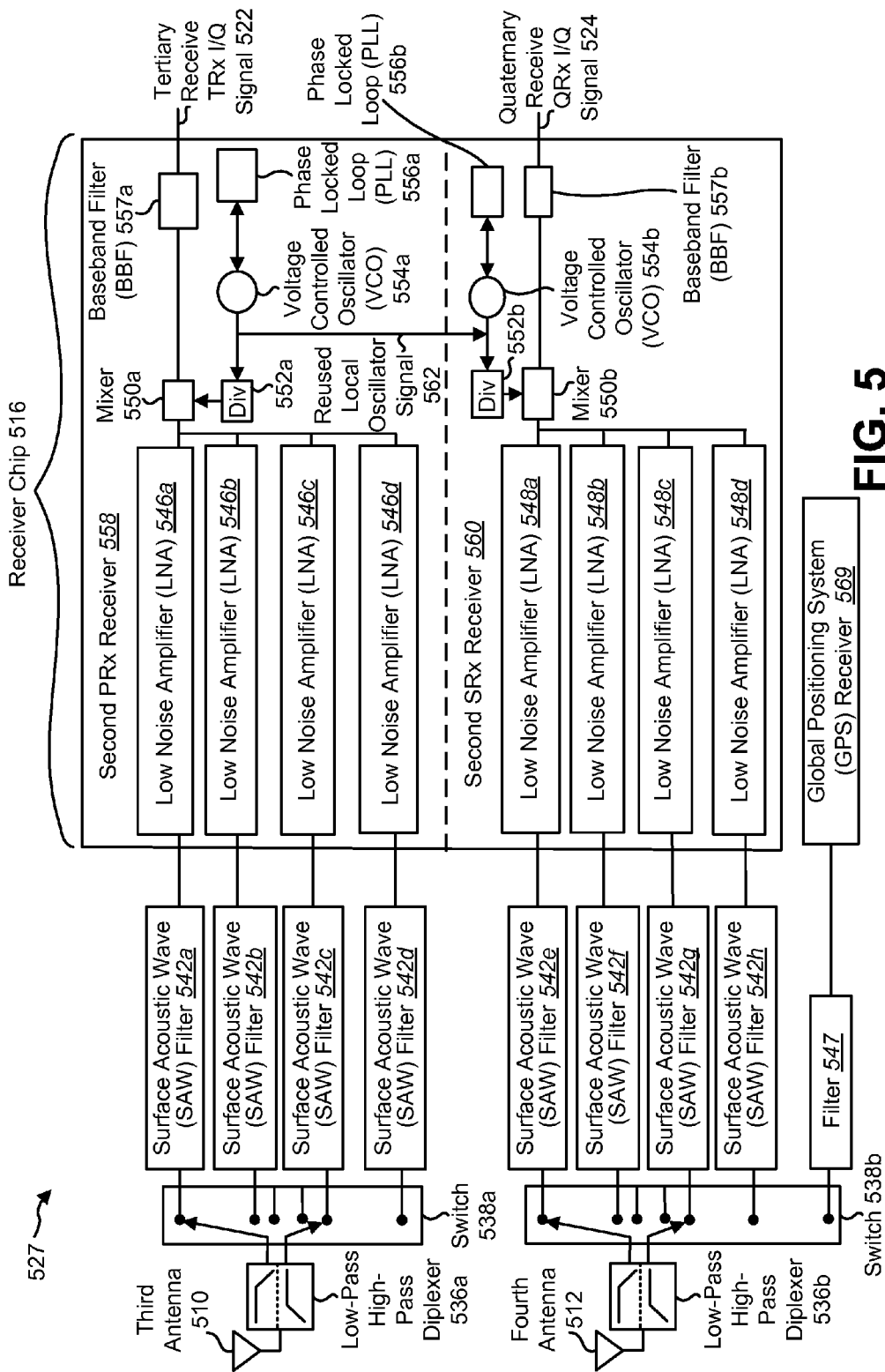


FIG. 4





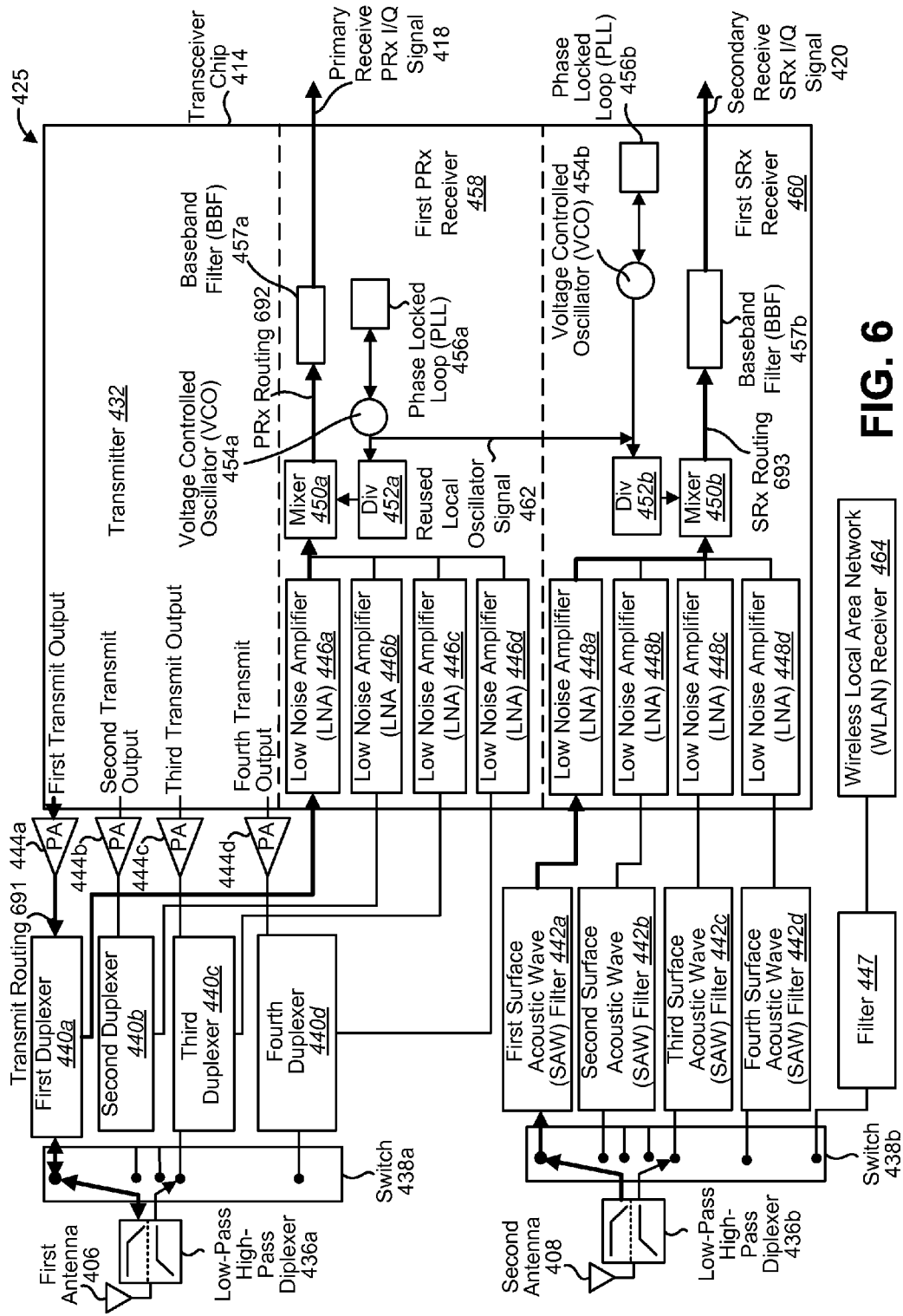


FIG. 6

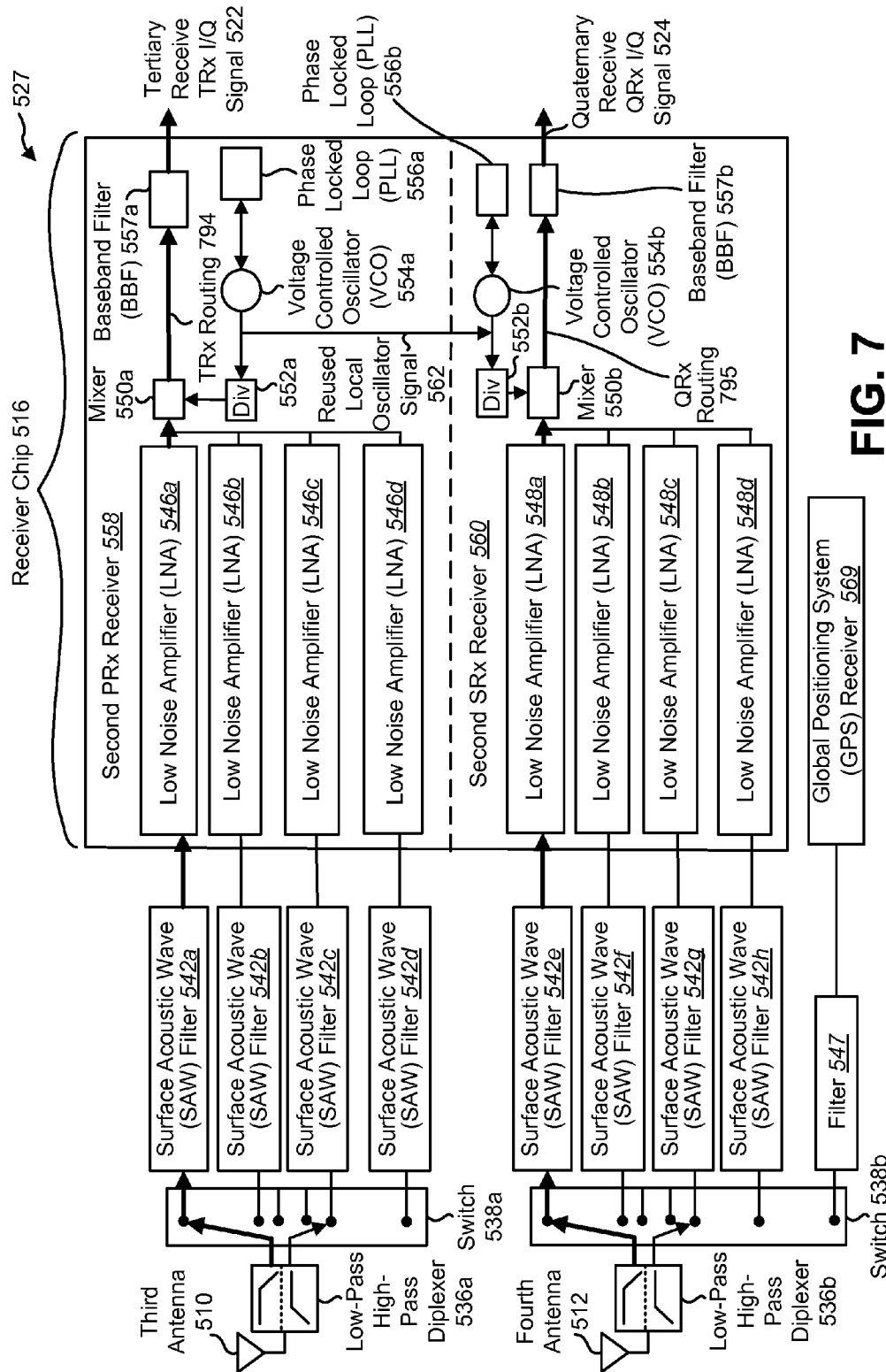


FIG. 7

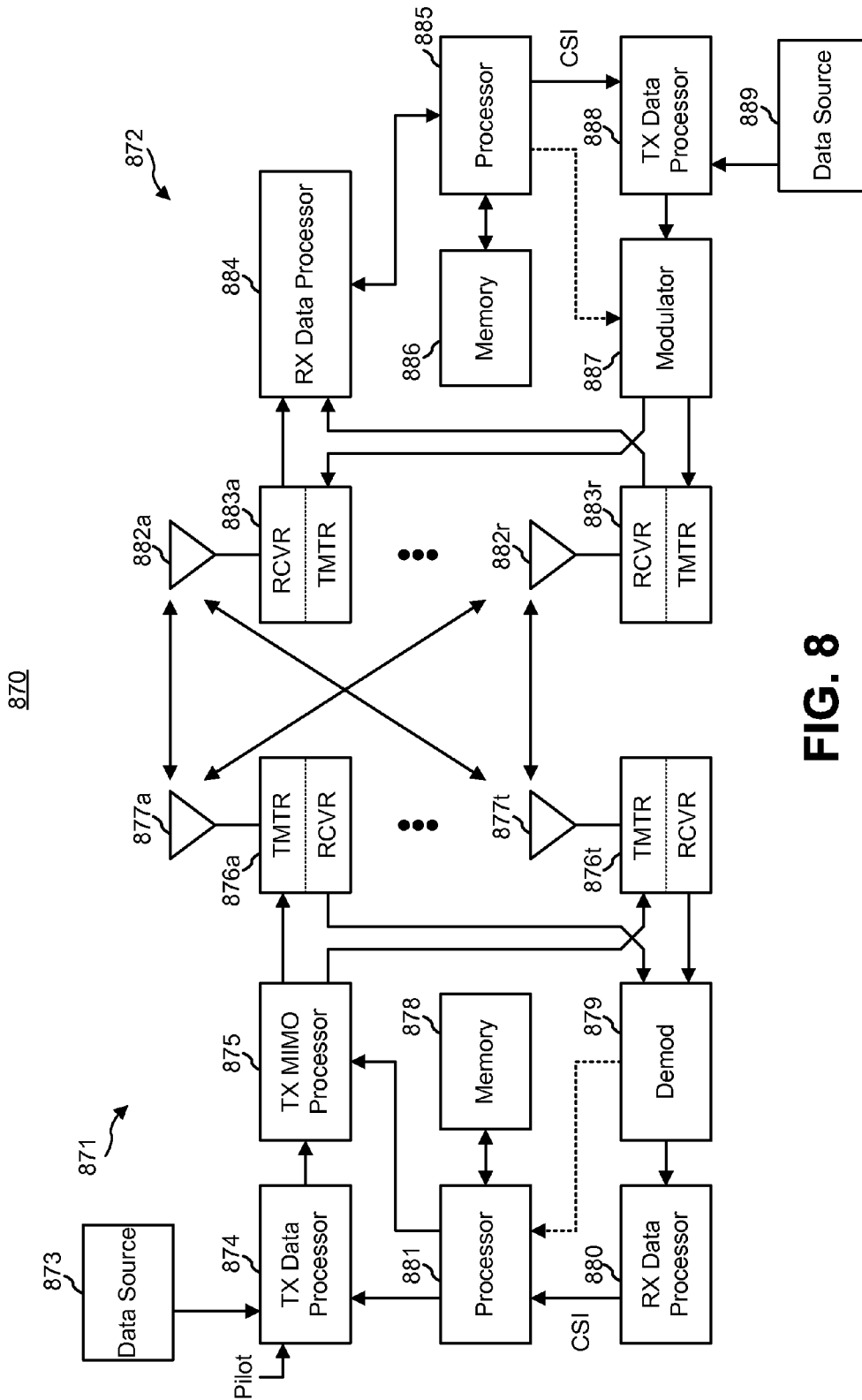


FIG. 8

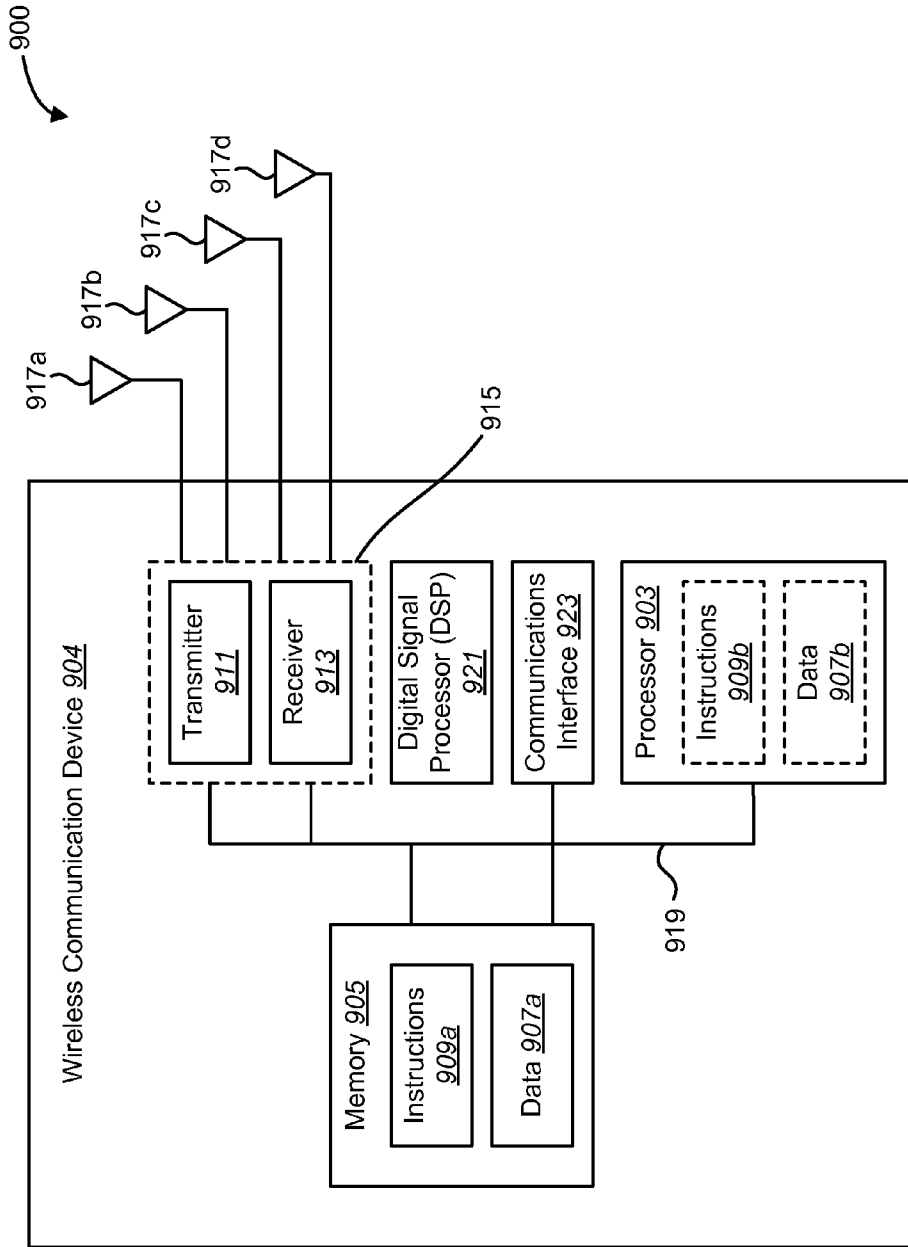


FIG. 9

# MULTIPLE-INPUT AND MULTIPLE-OUTPUT CARRIER AGGREGATION RECEIVER REUSE ARCHITECTURE

## TECHNICAL FIELD

The present disclosure relates generally to wireless devices for communication systems. More specifically, the present disclosure relates to systems and methods for a multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture.

## BACKGROUND

Electronic devices (cellular telephones, wireless modems, computers, digital music players, Global Positioning System units, Personal Digital Assistants, gaming devices, etc.) have become a part of everyday life. Small computing devices are now placed in everything from automobiles to housing locks. The complexity of electronic devices has increased dramatically in the last few years. For example, many electronic devices have one or more processors that help control the device, as well as a number of digital circuits to support the processor and other parts of the device.

These electronic devices may communicate wirelessly with each other and with a network. As the demand for information by these electronic devices has increased, the downlink throughput has also increased. One such way to increase downlink throughput is the use of carrier aggregation. In carrier aggregation, multiple carriers may be aggregated on the physical layer to provide the required bandwidth (and thus the required throughput).

It may be desirable for an electronic device to maximize battery life. Because an electronic device often runs on a battery with a limited operation time, reductions in the power consumption of an electronic device may increase the desirability and functionality of the electronic device.

The electronic devices have also become smaller and cheaper. To facilitate both the decrease in size and the decrease in cost, additional circuitry and more complex circuitry are being used on integrated circuits. Thus, any reduction in the die area used by circuitry may reduce both the size and cost of an electronic device. Benefits may be realized by improvements to electronic devices that minimize the cost and size of the electronic device while also minimizing the power consumption of the electronic device.

## SUMMARY

A wireless communication device configured for receiving a wireless multiple-input and multiple-output signal is described. The wireless communication device includes a first multiple-input and multiple-output carrier aggregation receiver reuse architecture. The first multiple-input and multiple-output carrier aggregation receiver reuse architecture includes a first antenna, a second antenna and a transceiver chip. The first multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a first carrier aggregation receiver path. The wireless communication device also includes a second multiple-input and multiple-output carrier aggregation receiver reuse architecture. The second multiple-input and multiple-output carrier aggregation receiver reuse architecture includes a third antenna, a fourth antenna and a receiver chip. The second multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a second carrier aggregation receiver path.

The wireless communication device may not require a power splitter, an external low noise amplifier or die-to-die signal routing. The transceiver chip may include a transmitter, first primary receiver and a first secondary receiver. The receiver chip may include a second primary receiver and a second secondary receiver. Each receiver may include multiple low noise amplifiers.

A first routing may be used from the first antenna through the first primary receiver to obtain a primary receive inphase/quadrature signal. A second routing may be used from the second antenna through the first secondary receiver to obtain a secondary receive inphase/quadrature signal. A third routing may be used from the third antenna through the second primary receiver to obtain a tertiary receive inphase/quadrature signal. A fourth routing may be used from the fourth antenna through the second secondary receiver to obtain a quaternary receive inphase/quadrature signal.

The first routing may pass through a duplexer and through a low noise amplifier on the first primary receiver. The second routing may pass through a surface acoustic wave filter and through a low noise amplifier on the first secondary receiver. The third routing may pass through a surface acoustic wave filter and through a low noise amplifier on the second primary receiver. The fourth routing may pass through a surface acoustic wave filter and through a low noise amplifier on the second secondary receiver.

Only two synthesizers may be running on the wireless communication device when the wireless communication device is receiving multiple-input and multiple-output communications. The first primary receiver may include a first synthesizer. The second primary receiver may include a second synthesizer. The first synthesizer may be shared with the first secondary receiver. The second synthesizer may be shared with the second secondary receiver.

The wireless communication device may be configured to receive 4Rx multiple-input and multiple-output communications using the first antenna, the second antenna, the third antenna and the fourth antenna. The second antenna may be a wireless local area network antenna. The fourth antenna may be a global positioning system antenna.

A method for receiving a multiple-input and multiple-output wireless signal is also described. A first multiple-input and multiple-output wireless signal is received using a first antenna. The first multiple-input and multiple-output wireless signal is routed through a first primary receiver on a transceiver chip to obtain a primary receive inphase/quadrature signal. A second multiple-input and multiple-output wireless signal is received using a second antenna. The second multiple-input and multiple-output wireless signal is routed through a first secondary receiver on the transceiver chip to obtain a secondary receive inphase/quadrature signal. A third multiple-input and multiple-output wireless signal is received using a third antenna. The third multiple-input and multiple-output wireless signal is routed through a second primary receiver on a receiver chip to obtain a tertiary receive inphase/quadrature signal. A fourth multiple-input and multiple-output wireless signal is received using a fourth antenna. The fourth multiple-input and multiple-output wireless signal is routed through a second secondary receiver on the receiver chip to obtain a quaternary receive inphase/quadrature signal.

A receive signal may be obtained from the primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive inphase/quadrature signal. The primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive

inphase/quadrature signal may be passed through a baseband digital modem to obtain the receive signal. The method may be performed by a wireless communication device.

An apparatus for receiving a multiple-input and multiple-output wireless signal is described. The apparatus includes means for receiving a first multiple-input and multiple-output wireless signal. The apparatus also includes means for routing the first multiple-input and multiple-output wireless signal through a first primary receiver on a transceiver chip to obtain a primary receive inphase/quadrature signal. The apparatus further includes means for receiving a second multiple-input and multiple-output wireless signal. The apparatus also includes means for routing the second multiple-input and multiple-output wireless signal through a first secondary receiver on the transceiver chip to obtain a secondary receive inphase/quadrature signal. The apparatus further includes means for receiving a third multiple-input and multiple-output wireless signal. The apparatus also includes means for routing the third multiple-input and multiple-output wireless signal through a second primary receiver on a receiver chip to obtain a tertiary receive inphase/quadrature signal. The apparatus further includes means for receiving a fourth multiple-input and multiple-output wireless signal. The apparatus also includes means for routing the fourth multiple-input and multiple-output wireless signal through a second secondary receiver on the receiver chip to obtain a quaternary receive inphase/quadrature signal.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a wireless communication device for use in the present systems and methods;

FIG. 2 is a block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture and a second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture on a wireless communication device;

FIG. 3 is a flow diagram of a method for receiving a wireless multiple-input and multiple-output (MIMO) signal;

FIG. 4 is a block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture;

FIG. 5 is a block diagram illustrating a second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture;

FIG. 6 is another block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture;

FIG. 7 is another block diagram illustrating a second multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture;

FIG. 8 is a block diagram of a transmitter and receiver in a multiple-input and multiple-output (MIMO) system; and

FIG. 9 illustrates certain components that may be included within a wireless communication device.

#### DETAILED DESCRIPTION

The 3<sup>rd</sup> Generation Partnership Project (3GPP) is a collaboration between groups of telecommunications associations that aims to define a globally applicable 3<sup>rd</sup> generation (3G) mobile phone specification. 3GPP Long Term Evolution (LTE) is a 3GPP project aimed at improving the Universal Mobile Telecommunications System (UMTS) mobile phone standard. The 3GPP may define specifications for the next generation of mobile networks, mobile systems and mobile

devices. In 3GPP LTE, a mobile station or device may be referred to as a “user equipment” (UE).

3GPP specifications are based on evolved Global System for Mobile Communications (GSM) specifications, which are generally known as the Universal Mobile Telecommunications System (UMTS). 3GPP standards are structured as releases. Discussion of 3GPP thus frequently refers to the functionality in one release or another. For example, Release 99 specifies the first UMTS 3<sup>rd</sup> generation (3G) networks, incorporating a CDMA air interface. Release 6 integrates operation with wireless local area networks (LAN) networks and adds High Speed Uplink Packet Access (HSUPA). Release 8 introduces dual downlink carriers and Release 9 extends dual carrier operation to uplink for UMTS.

CDMA2000 is a family of 3<sup>rd</sup> generation (3G) technology standards that use code division multiple access (CDMA) to send voice, data and signaling between wireless devices. CDMA2000 may include CDMA2000 1X, CDMA2000 EV-DO Rev. 0, CDMA2000 EV-DO Rev. A and CDMA2000 EV-DO Rev. B. 1× or 1×RTT refers to the core CDMA2000 wireless air interface standard. 1× more specifically refers to 1 times Radio Transmission Technology and indicates the same radio frequency (RF) bandwidth as used in IS-95. 1×RTT adds 64 additional traffic channels to the forward link. EV-DO refers to Evolution-Data Optimized. EV-DO is a telecommunications standard for the wireless transmission of data through radio signals.

FIG. 1 shows a wireless communication device **104** for use in the present systems and methods. A wireless communication device **104** 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 **104** may be a cellular phone, a personal digital assistant (PDA), a wireless device, a wireless modem, a handheld device, a laptop computer, a tablet computer, a PC card, compact flash, an external or internal modem, a wireline phone, etc. A wireless communication device **104** may be mobile or stationary. A wireless communication device **104** 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 **104**, and the uplink (or reverse link) refers to the communication link from a wireless communication device **104** to a base station. Uplink and downlink may refer to the communication link or to the carriers used for the communication link.

A wireless communication device **104** 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 **104**. 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 **104**. 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, respec-

tively, 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 **104** 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, 3<sup>rd</sup> Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems and spatial division multiple access (SDMA) systems.

As the demand for information by wireless communication devices **104** increases, the downlink throughput has also increased. One way to increase the downlink throughput is the use of carrier aggregation. In carrier aggregation, multiple carriers may be aggregated on the physical layer to provide the required bandwidth (and thus the required throughput). Carrier aggregation may use two antennas and four receivers. Typically, two of the receivers are on a first chip and two of the receivers are on a second chip. If the chips are reused for non-carrier aggregation, only two of the receivers may be used. However, the additional unused receivers (in non-carrier aggregation) may be used to support 4Rx paths. This may be accomplished by adding two additional antennae or by reusing the existing wireless local area network (WLAN) antenna and global positioning system (GPS) antenna.

The wireless communication device **104** may include a first antenna **106**, a second antenna **108**, a third antenna **110** and a fourth antenna **112**. In one configuration, the first antenna **106** may be a primary antenna, the second antenna **108** may be a wireless local area network (WLAN) antenna or a Bluetooth antenna, the third antenna **110** may be a secondary antenna and the fourth antenna **112** may be a global positioning system (GPS) antenna.

A transceiver chip **114** on the wireless communication device **104** may be coupled to the first antenna **106** and the second antenna **108**. The transceiver chip **114** may include a transmitter **132**, a first PRx receiver **158a** and a first SRx receiver **160a**. In one configuration, the transceiver chip **114** may also include a wireless local area network (WLAN)/Bluetooth receiver (i.e., when the second antenna **108** is a wireless local area network (WLAN) antenna or a Bluetooth antenna). The first PRx receiver **158a** may output a primary receive PRx inphase/quadrature (I/Q) signal **118** to a baseband digital modem **126** on the wireless communication device **104**. The first SRx receiver **160a** may output a secondary receive SRx inphase/quadrature (I/Q) signal **120** to the baseband digital modem **126**. The configuration of the first antenna **106**, the second antenna **108** and the transceiver chip **114** may be referred to as a first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **125**. This is because the first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **125** may reuse a carrier aggregation receiver

architecture on the wireless communication device **104** to support multiple-input and multiple-output (MIMO) communications (such as the 4Rx multiple-input and multiple-output (MIMO) shown).

A receiver chip **116** on the wireless communication device **104** may be coupled to the second antenna **108** and the third antenna **110**. The receiver chip **116** may include a second PRx receiver **158b** and a second SRx receiver **160b**. In one configuration, the receiver chip **116** may also include a global positioning system (GPS) receiver (i.e., when the fourth antenna **112** is a global positioning system (GPS) antenna). The second PRx receiver **158b** may output a tertiary receive TRx inphase/quadrature (I/Q) signal **122** to the baseband digital modem **126**. The second SRx receiver **160b** may output a quaternary receive QRx inphase/quadrature (I/Q) signal **124** to the baseband digital modem **126**. The configuration of the third antenna **110**, the fourth antenna **112** and the receiver chip **116** may be referred to as a second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **127**. The second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **127** may also reuse a carrier aggregation receiver architecture on the wireless communication device **104** to support multiple-input and multiple-output (MIMO) communications.

The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **125** and the second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **127** may have only a total of two synthesizers running (e.g., one in the first PRx receiver **158a** and one in the second PRx receiver **158b**). A synthesizer may refer to a frequency generator such as a local oscillator or a voltage controlled oscillator.

The baseband digital modem **126** may perform processing on the primary receiver PRx inphase/quadrature (I/Q) signal **118**, the secondary receive SRx inphase/quadrature (I/Q) signal **120**, the tertiary receive TRx inphase/quadrature (I/Q) signal **122** and the quaternary receive QRx inphase/quadrature (I/Q) signal **124**. For example, the baseband digital modem **126** may convert the signals to the digital domain using analog-to-digital converters (ADCs) and perform digital processing on the signals using digital signal processors (DSPs). The baseband digital modem **126** may then output a receive signal **128**.

FIG. 2 is a block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **225** and a second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **227** on a wireless communication device **204**. The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **225** of FIG. 2 may be one configuration of the first multiple-input and multiple-output (MIMO) carrier aggregation receiver architecture **125** of FIG. 1. The second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **227** of FIG. 2 may be one configuration of the second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **127** of FIG. 1.

The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **225** may include a primary antenna **206**, a wireless local area network (WLAN) antenna **208** and a transceiver chip **214**. The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **225** may reuse an existing carrier aggregation receiver architecture for multiple-input and multiple-output (MIMO) receiving. The second multiple-input and multiple-output (MIMO) carrier aggregation



receiver reuse architecture **227** may include a secondary antenna **210**, a global positioning system (GPS) antenna **212** and a receiver chip **216**. The second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **227** may also reuse an existing carrier aggregation receiver architecture for multiple-input and multiple-output (MIMO) receiving.

The primary antenna **206**, wireless local area network (WLAN) antenna **208**, secondary antenna **210** and global positioning system (GPS) antenna **212** may each receive a wireless multiple-input and multiple-output (MIMO) signal **230** in the low band **232** as part of multiple-input and single-output (MISO) mode. No signals may be received in the mid band **234**. The transceiver chip **214** may output a primary receive PRx inphase/quadrature (I/Q) signal **218** in the low band **232** and a secondary receive SRx inphase/quadrature (I/Q) signal **220** in the low band **232**. The receiver chip **216** may output a tertiary receive TRx inphase/quadrature (I/Q) signal **222** in the low band **232** and a quaternary receive QRx inphase/quadrature (I/Q) signal **224** in the low band **232**.

FIG. **3** is a flow diagram of a method **300** for receiving a wireless multiple-input and multiple-output (MIMO) signal. The method **300** may be performed by a wireless communication device **104**. The wireless communication device **104** may be operating in multiple-input and single-output (MISO) mode. In multiple-input and single-output (MISO) mode, the wireless communication device **104** may receive a wireless multiple-input and multiple-output (MIMO) signal **230** using four discrete antennas. The wireless communication device **104** may then use digital processing to obtain a receive signal **128**. Because each of the antennas are physically separated from the other antennas (i.e., located on different places on the wireless communication device **104**), each antenna may receive a different version of the wireless multiple-input and multiple-output (MIMO) signal **230**.

The wireless communication device **104** may receive **302** a first multiple-input and multiple-output (MIMO) signal using a first antenna. The first multiple-input and multiple-output (MIMO) signal refers to the version of the wireless multiple-input and multiple-output (MIMO) signal **230** received by the first antenna **106**. The wireless communication device **104** may route **304** the first multiple-input and multiple-output (MIMO) signal through a first PRx receiver **158a** on a transceiver chip **114** to obtain a primary receive PRx inphase/quadrature (I/Q) signal **118**. The wireless communication device **104** may also receive **306** a second multiple-input and multiple-output (MIMO) signal using a second antenna **108**. The second multiple-input and multiple-output (MIMO) signal refers to the version of the wireless multiple-input and multiple-output (MIMO) signal **230** received by the second antenna **108**. The wireless communication device **104** may route **308** the second multiple-input and multiple-output (MIMO) signal through a first SRx receiver **160a** on the transceiver chip **114** to obtain a secondary receive SRx inphase/quadrature (I/Q) signal **120**.

The wireless communication device **104** may receive **310** a third multiple-input and multiple-output (MIMO) signal using a third antenna **110**. The third multiple-input and multiple-output (MIMO) signal refers to the version of the wireless multiple-input and multiple-output (MIMO) signal **230** received by the third antenna **110**. The wireless communication device **104** may route **312** the third multiple-input and multiple-output (MIMO) signal through a second PRx receiver **158b** on a receiver chip **116** to obtain a tertiary receive TRx inphase/quadrature (I/Q) signal **122**. The wireless communication device **104** may also receive **314** a fourth multiple-input and multiple-output (MIMO) signal using a

fourth antenna **112**. The fourth multiple-input and multiple-output (MIMO) signal refers to the version of the wireless multiple-input and multiple-output (MIMO) signal **230** received by the fourth antenna **112**. The wireless communication device **104** may route **316** the fourth multiple-input and multiple-output (MIMO) signal through a second SRx receiver **160b** on the receiver chip **116** to obtain a quaternary receive QRx inphase/quadrature (I/Q) signal **124**. The wireless communication device **104** may obtain **318** a receive signal **128** from the primary receive PRx inphase/quadrature (I/Q) signal **118**, the secondary receive SRx inphase/quadrature (I/Q) signal **120**, the tertiary receive TRx inphase/quadrature (I/Q) signal **122** and the quaternary receive QRx inphase/quadrature (I/Q) signal **124**.

FIG. **4** is a block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **425**. The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **425** of FIG. **4** may be one configuration of the first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **125** of FIG. **1**. The first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **425** may include a first antenna **406**, a first low-pass high-pass diplexer **436a**, a first switch **438a**, four duplexers **440a-d**, a second antenna **408**, a second low-pass high-pass diplexer **436b**, a second switch **438b**, four surface acoustic wave (SAW) filters **442a-d** and a transceiver chip **414**. As discussed above, in one configuration, the second antenna **408** may be a wireless local area network (WLAN) antenna **208**.

The first antenna **406** may be coupled to the first low-pass high-pass diplexer **436a**. A low-pass high-pass diplexer **436** may bundle low band frequencies into one signal and high band (or midband) frequencies into another signal, thus allowing the first antenna **406** to pass both low band and midband signals to the transceiver chip **414**. The first low-pass high-pass diplexer **436a** may be coupled to the first switch **438a**. The first switch **438a** may have two inputs (the signal that includes the bundled low band frequencies and the signal that includes the bundled high band frequencies) and multiple outputs. In one configuration, the first switch **438a** may have six possible outputs to the four duplexers **440** (representing the six possible configurations of diplexer **440** pairs). The four duplexers **440** may include a first diplexer **440a**, a second diplexer **440b**, a third diplexer **440c** and a fourth diplexer **440d**. In one configuration, the first diplexer **440a** and the second diplexer **440b** may be used for a low band while the third diplexer **440c** and the fourth diplexer **440d** are used for a midband.

The transceiver chip **414** may include a transmitter **432**, a first PRx receiver **458** and a first SRx receiver **460**. The transmitter **432** may include four transmit outputs: a first transmit output, a second transmit output, a third transmit output and a fourth transmit output. In one configuration, the first transmit output and the second transmit output may be low band outputs while the third transmit output and the fourth transmit output are midband outputs.

The first transmit output may be coupled to the first diplexer **440a** via a power amplifier (PA) **444a**. The second transmit output may be coupled to the second diplexer **440b** via a power amplifier (PA) **444b**. The third transmit output may be coupled to the third diplexer **440c** via a power amplifier (PA) **444c**. The fourth transmit output may be coupled to the fourth diplexer **440d** via a power amplifier (PA) **444d**.

The first PRx receiver **458** may include four low noise amplifiers (LNAs) **446a-d**. The first low noise amplifier (LNA) **446a** may be coupled to the first diplexer **440a**, the

second low noise amplifier (LNA) **446b** may be coupled to the second duplexer **440b**, the third low noise amplifier (LNA) **446c** may be coupled to the third duplexer **440c** and the fourth low noise amplifier (LNA) **446d** may be coupled to the fourth duplexer **440d**. In one configuration, the first low noise amplifier (LNA) **446a** and the second low noise amplifier (LNA) **446b** may be low band low noise amplifiers (LNAs) while the third low noise amplifier (LNA) **446c** and the fourth low noise amplifier (LNA) **446d** are midband low noise amplifiers (LNAs).

The first PRx receiver **458** may also include a mixer **450a** (e.g., a downconverter). The mixer **450a** may be coupled to the output of the first low noise amplifier (LNA) **446a**, the output of the second low noise amplifier (LNA) **446b**, the output of the third low noise amplifier (LNA) **446c** and the output of the fourth low noise amplifier (LNA) **446d**.

The first PRx receiver **458** may include a phase locked loop (PLL) **456a**, a voltage controlled oscillator (VCO) **454a** and a Div stage **452a** that are used to generate the downconverting frequency for the mixer **450a**. The output of the mixer **450a** may be coupled to a baseband filter (BBF) **457a**. The baseband filter (BBF) **457a** may then output the primary receive PRx inphase/quadrature (I/Q) signal **418**.

The second antenna **408** may be coupled to the second low-pass high-pass diplexer **436b**. The second low-pass high-pass diplexer **436b** may be coupled to the second switch **438b**. The second switch **438b** may have two inputs (the signal that includes the bundled low band frequencies and the signal that includes the bundled high band frequencies) and multiple outputs. In one configuration, the second switch **438b** may have seven possible outputs to the four surface acoustic wave (SAW) filters **442a-d** and a filter **447** (representing the seven possible configurations of filter pairs). The filter **447** may be coupled to a wireless local area network (WLAN) receiver **464**. If the second antenna **408** is a wireless local area network (WLAN) antenna **208**, the filter **447** may filter wireless local area network (WLAN) received signals before passing the signals to the wireless local area network (WLAN) receiver **464**. In the first multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **425**, the input to the filter **447** is disabled.

The four surface acoustic wave (SAW) filters **442** may include a first surface acoustic wave (SAW) filter **442a**, a second surface acoustic wave (SAW) filter **442b**, a third surface acoustic wave (SAW) filter **442c** and a fourth surface acoustic wave (SAW) filter **442d**. In one configuration, the first surface acoustic wave (SAW) filter **442a** and the second surface acoustic wave (SAW) filter **442b** may be used for the low band while the third surface acoustic wave (SAW) filter **442c** and the fourth surface acoustic wave (SAW) filter **442d** are used for the midband.

The first SRx receiver **460** may include a first low noise amplifier (LNA) **448a** coupled to the first surface acoustic wave (SAW) filter **442a**, a second low noise amplifier (LNA) **448b** coupled to the second surface acoustic wave (SAW) filter **442b**, a third low noise amplifier (LNA) **448c** coupled to the third surface acoustic wave (SAW) filter **442c** and a fourth low noise amplifier (LNA) **448d** coupled to the fourth surface acoustic wave (SAW) filter **442d**. In one configuration, the first low noise amplifier (LNA) **448a** and the second low noise amplifier (LNA) **448b** may be low band low noise amplifiers (LNAs) while the third low noise amplifier (LNA) **448c** and the fourth low noise amplifier (LNA) **448d** are midband low noise amplifiers (LNAs).

The first SRx receiver **460** may include a mixer **450b** coupled to the output of the first low noise amplifier (LNA) **448a**, the output of the second low noise amplifier (LNA)

**448b**, the output of the third low noise amplifier (LNA) **448c** and the output of the fourth low noise amplifier (LNA) **448d**. The first SRx receiver **460** may also include a phase locked loop (PLL) **456b**, a voltage controlled oscillator (VCO) **454b** and a Div stage **452b** that are used to generate a downconverting frequency for the mixer **450b**. When the wireless communication device **104** is operating in multiple-input and multiple-output (MIMO) mode, the voltage controlled oscillator (VCO) **454b** and the phase locked loop (PLL) **456b** may be deactivated. The Div stage **452b** may instead receive a reused local oscillator signal **462** generated by the voltage controlled oscillator (VCO) **454a** of the first PRx receiver **458**. The output of the mixer **450b** may be coupled to a baseband filter (BBF) **457b**. The baseband filter (BBF) **457b** may then output the secondary receive SRx inphase/quadrature (I/Q) signal **420**.

FIG. 5 is a block diagram illustrating a second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **527**. The second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **527** of FIG. 5 may be one configuration of the second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **127** of FIG. 1. The second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **527** may include a third antenna **510**, a third low-pass high-pass diplexer **536a**, a third switch **538a**, four surface acoustic wave (SAW) filters **542a-d** for the third antenna **510**, a fourth antenna **512**, a fourth low-pass high-pass diplexer **536b**, a fourth switch **538b**, four surface acoustic wave (SAW) filters **542e-h** for the fourth antenna **512** and a receiver chip **516**. As discussed above, in one configuration, the fourth antenna **512** may be a global positioning system (GPS) antenna **212**.

The third antenna **510** may be coupled to the third low-pass high-pass diplexer **536a**. The third low-pass high-pass diplexer **536a** may be coupled to the third switch **538a**. The third switch **538a** may have two inputs (the signal that includes the bundled low band frequencies and the signal that includes the bundled high band frequencies) and multiple outputs. In one configuration, the third switch **538a** may have six possible outputs to the four surface acoustic wave (SAW) filters **542a-d** for the third antenna **510** (representing the six possible configurations of surface acoustic wave (SAW) filter **542a-d** pairs). The four surface acoustic wave (SAW) filters **542a-d** for the third antenna **510** may include a first surface acoustic wave (SAW) filter **542a**, a second surface acoustic wave (SAW) filter **542b**, a third surface acoustic wave (SAW) filter **542c** and a fourth surface acoustic wave (SAW) filter **542d**. In one configuration, the first surface acoustic wave (SAW) filter **542a** and the second surface acoustic wave (SAW) filter **542b** may be used for a low band while the third surface acoustic wave (SAW) filter **542c** and the fourth surface acoustic wave (SAW) filter **542d** are used for a midband.

The receiver chip **516** may include a second PRx receiver **558** and a second SRx receiver **560**. The second PRx receiver **558** may include four low noise amplifiers (LNAs) **546a-d**. The first low noise amplifier (LNA) **546aa** may be coupled to the first surface acoustic wave (SAW) filter **542a**, the second low noise amplifier (LNA) **546ab** may be coupled to the second surface acoustic wave (SAW) filter **542b**, the third low noise amplifier (LNA) **546ac** may be coupled to the third surface acoustic wave (SAW) filter **542c** and the fourth low noise amplifier (LNA) **546ad** may be coupled to the fourth surface acoustic wave (SAW) filter **542d**. In one configuration, the first low noise amplifier (LNA) **546a** and the second low noise amplifier (LNA) **546b** may be low band low noise amplifiers

(LNAs) while the third low noise amplifier (LNA) **546c** and the fourth low noise amplifier (LNA) **546d** are midband low noise amplifiers (LNAs).

The second PRx receiver **558** may include a mixer **550a**. The mixer **550a** may be coupled to the output of the first low noise amplifier (LNA) **546a**, the output of the second low noise amplifier (LNA) **546b**, the output of the third low noise amplifier (LNA) **546c** and the output of the fourth low noise amplifier (LNA) **546d**.

The second PRx receiver **558** may include a phase locked loop (PLL) **556a**, a voltage controlled oscillator (VCO) **554a** and a Div stage **552a** that are used to generate the downconverting frequency for the mixer **550a**. The output of the mixer **550a** may be coupled to a baseband filter (BBF) **557a**. The baseband filter (BBF) **557a** may then output the tertiary receive TRx inphase/quadrature (I/Q) signal **522**.

The fourth antenna **512** may be coupled to the fourth low-pass high-pass diplexer **536b**. The fourth low-pass high-pass diplexer **536b** may be coupled to the fourth switch **538b**. The fourth switch **538b** may have two inputs (the signal that includes the bundled low band frequencies and the signal that includes the bundled high band frequencies) and multiple outputs. In one configuration, the fourth switch **538b** may have seven possible outputs to the four surface acoustic wave (SAW) filters **542e-h** and a filter **547** (representing the seven possible configurations of filter pairs). The filter **547** may be coupled to a global positioning system (GPS) receiver **569**. If the fourth antenna **512** is a global positioning system (GPS) antenna **212**, the filter **547** may filter global positioning system (GPS) received signals before passing the signals to the global positioning system (GPS) receiver **569**. In the second multiple-input and multiple-output (MIMO) carrier aggregation receiver reuse architecture **527**, the input to the filter **547** is disabled.

In one configuration, the fifth surface acoustic wave (SAW) filter **542e** and the sixth surface acoustic wave (SAW) filter **542f** may be used for the low band while the seventh surface acoustic wave (SAW) filter **542g** and the eighth surface acoustic wave (SAW) filter **542h** are used for the midband.

The second SRx receiver **560** may include a first low noise amplifier (LNA) **548a** coupled to the fifth surface acoustic wave (SAW) filter **542e**, a second low noise amplifier (LNA) **548b** coupled to the sixth surface acoustic wave (SAW) filter **542f**, a third low noise amplifier (LNA) **548c** coupled to the seventh surface acoustic wave (SAW) filter **542g** and a fourth low noise amplifier (LNA) **548d** coupled to the eighth surface acoustic wave (SAW) filter **542h**. In one configuration, the first low noise amplifier (LNA) **548a** and the second low noise amplifier (LNA) **548b** may be low band low noise amplifiers (LNAs) while the third low noise amplifier (LNA) **548c** and the fourth low noise amplifier (LNA) **548d** are midband low noise amplifiers (LNAs).

The second SRx receiver **560** may include a mixer **550b** coupled to the output of the first low noise amplifier (LNA) **548a**, the output of the second low noise amplifier (LNA) **548b**, the output of the third low noise amplifier (LNA) **548c** and the output of the fourth low noise amplifier (LNA) **548d**. The second SRx receiver **560** may also include a phase locked loop (PLL) **556b**, a voltage controlled oscillator (VCO) **554b** and a Div stage **552b** that are used to generate a downconverting frequency for the mixer **550b**. When the wireless communication device **104** is operating in multiple-input and multiple-output (MIMO) mode, the voltage controlled oscillator (VCO) **554b** and the phase locked loop (PLL) **556b** may be deactivated (so that a total of only two synthesizers are running on the wireless communication device **104**). The Div stage **552b** may instead receive a reused local oscillator signal

**562** from the voltage controlled oscillator (VCO) **554a** of the second PRx receiver **558**. The output of the mixer **550b** may be coupled to a baseband filter (BBF) **557b**. The baseband filter (BBF) **557b** may then output the quaternary receive QRx inphase/quadrature (I/Q) signal **524**.

FIG. 6 is another block diagram illustrating a first multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **425**. The first multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **425** of FIG. 6 may be the first multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **425** of FIG. 4. The first antenna **406** and the second antenna **408** may each receive a wireless multiple-input and multiple-output (MIMO) signal **230**. Due to a physical separation between the first antenna **406** and the second antenna **408**, the first antenna **406** may receive a different version of the wireless multiple-input and multiple-output (MIMO) signal **230** than the second antenna **408**.

A transmit routing **691** is shown from the transmitter **432** to the first antenna **406**. The transmit routing **691** may be used for transmitting signals. The transmit routing **691** may pass through the first power amplifier (PA) **444a**, the first duplexer **440a** and the low-pass high-pass diplexer **436a**. A PRx routing **692** from the first antenna **406** through the first PRx receiver **458** to obtain the primary receive PRx inphase/quadrature (I/Q) signal **418** is also shown. The PRx routing **692** may pass through the first duplexer **440a**, the first low noise amplifier (LNA) **446a** of the first PRx receiver **458**, the mixer **450a** and the baseband filter (BBF) **457a**. An SRx routing **693** from the second antenna **408** through the first SRx receiver **460** to obtain the secondary receive SRx inphase/quadrature (I/Q) signal **420** is shown. The SRx routing **693** may pass through the first surface acoustic wave (SAW) filter **442a**, the first low noise amplifier (LNA) **448a** of the first SRx receiver **460**, the mixer **450b** and the baseband filter (BBF) **457b**. The PRx routing **692** and the SRx routing **693** may reuse a carrier aggregation receiver architecture.

FIG. 7 is another block diagram illustrating a second multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **527**. The second multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **527** of FIG. 7 may be the second multiple-input and multiple-output (MIMO) carrier aggregation reuse architecture **527** of FIG. 5. The third antenna **510** and the fourth antenna **512** may each receive a wireless multiple-input and multiple-output (MIMO) signal **230**. Due to a physical separation between the third antenna **510** and the fourth antenna **512**, the third antenna **510** may receive a different version of the wireless multiple-input and multiple-output (MIMO) signal **230** than the fourth antenna **512**.

A TRx routing **794** from the third antenna **510** through the second PRx receiver **558** to obtain the tertiary receive TRx inphase/quadrature (I/Q) signal **522** is shown. The TRx routing **794** may pass through the first surface acoustic wave (SAW) filter **542a**, the first low noise amplifier (LNA) **546a** of the second PRx receiver **558**, the mixer **550a** and the baseband filter (BBF) **557a**. A QRx routing **795** from the fourth antenna **512** through the second SRx receiver **560** to obtain the quaternary receive QRx inphase/quadrature (I/Q) signal **524** is also shown. The QRx routing **795** may pass through the fifth surface acoustic wave (SAW) filter **542e**, the first low noise amplifier (LNA) **548a** of the second SRx receiver **560**, the mixer **550b** and the baseband filter (BBF) **557b**. The TRx routing **794** and the QRx routing **795** may reuse a carrier aggregation receiver architecture.

FIG. 8 is a block diagram of a transmitter **871** and receiver **872** in a multiple-input and multiple-output (MIMO) system

**870.** In the transmitter **871**, traffic data for a number of data streams is provided from a data source **873** to a transmit (TX) data processor **874**. Each data stream may then be transmitted over a respective transmit antenna **877a** through **877t**. The transmit (TX) data processor **874** may format, code, and interleave the traffic data for each data stream based on a particular coding scheme selected for that data stream to provide coded data.

The coded data for each data stream may be multiplexed with pilot data using OFDM techniques. The pilot data may be a known data pattern that is processed in a known manner and used at the receiver **872** to estimate the channel response. The multiplexed pilot and coded data for each stream is then modulated (i.e., symbol mapped) based on a particular modulation scheme (e.g., binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), multiple phase shift keying (M-PSK) or multi-level quadrature amplitude modulation (M-QAM)) selected for that data stream to provide modulation symbols. The data rate, coding and modulation for each data stream may be determined by instructions performed by a processor.

The modulation symbols for all data streams may be provided to a transmit (TX) multiple-input multiple-output (MIMO) processor **875**, which may further process the modulation symbols (e.g., for OFDM). The transmit (TX) multiple-input multiple-output (MIMO) processor **875** then provides NT modulation symbol streams to NT transmitters (TMTR) **876a** through **876t**. The TX transmit (TX) multiple-input multiple-output (MIMO) processor **875** may apply beamforming weights to the symbols of the data streams and to the antenna **877** from which the symbol is being transmitted.

Each transmitter **876** may receive and process a respective symbol stream to provide one or more analog signals, and further condition (e.g., amplify, filter and upconvert) the analog signals to provide a modulated signal suitable for transmission over the multiple-input and multiple-output (MIMO) channel. NT modulated signals from transmitters **876a** through **876t** are then transmitted from NT antennas **877a** through **877t**, respectively.

At the receiver **872**, the transmitted modulated signals are received by NR antennas **882a** through **882r** and the received signal from each antenna **882** is provided to a respective receiver (RCVR) **883a** through **883r**. Each receiver **883** may condition (e.g., filter, amplify and downconvert) a respective received signal, digitize the conditioned signal to provide samples, and further process the samples to provide a corresponding "received" symbol stream.

An RX data processor **884** then receives and processes the NR received symbol streams from NR receivers **883** based on a particular receiver processing technique to provide NT "detected" symbol streams. The RX data processor **884** then demodulates, deinterleaves and decodes each detected symbol stream to recover the traffic data for the data stream. The processing by RX data processor **884** is complementary to that performed by TX multiple-input and multiple-output (MIMO) processor **875** and TX data processor **874** at transmitter system **871**.

A processor **885** may periodically determine which precoding matrix to use. The processor **885** may store information on and retrieve information from memory **886**. The processor **885** formulates a reverse link message comprising a matrix index portion and a rank value portion. The reverse link message may be referred to as channel state information (CSI). The reverse link message may comprise various types of information regarding the communication link and/or the received data stream. The reverse link message is then processed by a TX data processor **888**, which also receives traffic

data for a number of data streams from a data source **889**, modulated by a modulator **887**, conditioned by transmitters **883a** through **883r**, and transmitted back to the transmitter **871**.

At the transmitter **871**, the modulated signals from the receiver **872** are received by antennas **877**, conditioned by receivers **876**, demodulated by a demodulator **879**, and processed by an RX data processor **880** to extract the reverse link message transmitted by the receiver system **872**. A processor **881** may receive channel state information (CSI) from the RX data processor **880**. The processor **881** may store information on and retrieve information from memory **878**. The processor **881** then determines which pre-coding matrix to use for determining the beamforming weights and then processes the extracted message.

FIG. 9 illustrates certain components that may be included within a wireless communication device **904**. The wireless communication device **904** may be an access terminal, a mobile station, a user equipment (UE), etc. The wireless communication device **904** includes 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 wireless communication device **904** of FIG. 9, in an alternative configuration, a combination of processors (e.g., an ARM and DSP) could be used.

The wireless communication device **904** 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 **907a** and instructions **909a** may be stored in the memory **905**. The instructions **909a** may be executable by the processor **903** to implement the methods disclosed herein. Executing the instructions **909a** may involve the use of the data **907a** that is stored in the memory **905**. When the processor **903** executes the instructions **909**, various portions of the instructions **909b** may be loaded onto the processor **903**, and various pieces of data **907b** may be loaded onto the processor **903**.

The wireless communication device **904** may also include a transmitter **911** and a receiver **913** to allow transmission and reception of signals to and from the wireless communication device **904** via a first antenna **917a**, a second antenna **917b**, a third antenna **917c** and a fourth antenna **917d**. The transmitter **911** and receiver **913** may be collectively referred to as a transceiver **915**. The wireless communication device **904** may also include (not shown) multiple transmitters, additional antennas, multiple receivers and/or multiple transceivers.

The wireless communication device **904** may include a digital signal processor (DSP) **921**. The wireless communication device **904** may also include a communications interface **923**. The communications interface **923** may allow a user to interact with the wireless communication device **904**.

The various components of the wireless communication device **904** 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**.

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, sub-routines, functions, procedures, etc. “Instructions” and “code” may comprise a single computer-readable statement or many computer-readable statements.

The functions described herein may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions on a computer-readable medium. The terms “computer-readable medium” or “computer-program product” refers to any available medium that can be accessed by a computer. By way of example, and not limitation, a computer-readable medium may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. 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.

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 FIG. 3, 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 wireless communication device configured for receiving a wireless multiple-input and multiple-output signal, comprising:

a first multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:

a first antenna coupled to a transceiver chip;  
a second antenna coupled to the transceiver chip, wherein the second antenna is a wireless local area network antenna; and

the transceiver chip, wherein the transceiver chip comprises a first primary receiver and a first secondary receiver that are configured for both carrier aggregation operation and multiple-input and multiple-output operation; and

a second multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:

a third antenna coupled to a receiver chip;  
a fourth antenna coupled to the receiver chip, wherein the fourth antenna is a global positioning system antenna; and

the receiver chip, wherein the receiver chip comprises a second primary receiver and a second secondary receiver that are configured for both carrier aggregation operation and multiple-input and multiple-output operation.

2. The wireless communication device of claim 1, wherein the wireless communication device does not require a power splitter, an external low noise amplifier or die-to-die signal routing.

3. The wireless communication device of claim 1, wherein the transceiver chip comprises:

a transmitter,  
wherein each receiver comprises multiple low noise amplifiers.

17

4. The wireless communication device of claim 3, wherein a first routing is used from the first antenna through the first primary receiver to obtain a primary receive inphase/quadrature signal, wherein a second routing is used from the second antenna through the first secondary receiver to obtain a secondary receive inphase/quadrature signal, wherein a third routing is used from the third antenna through the second primary receiver to obtain a tertiary receive inphase/quadrature signal, and wherein a fourth routing is used from the fourth antenna through the second secondary receiver to obtain a quaternary receive inphase/quadrature signal.

5. The wireless communication device of claim 4, wherein the first routing passes through a duplexer and through a low noise amplifier on the first primary receiver.

6. The wireless communication device of claim 4, wherein the second routing passes through a surface acoustic wave filter and through a low noise amplifier on the first secondary receiver.

7. The wireless communication device of claim 4, wherein the third routing passes through a surface acoustic wave filter and through a low noise amplifier on the second primary receiver.

8. The wireless communication device of claim 4, wherein the fourth routing passes through a surface acoustic wave filter and through a low noise amplifier on the second secondary receiver.

9. The wireless communication device of claim 3, wherein only two synthesizers are running on the wireless communication device when the wireless communication device is receiving multiple-input and multiple-output communications.

10. The wireless communication device of claim 9, wherein the first primary receiver comprises a first synthesizer, wherein the second primary receiver comprises a second synthesizer, wherein the first synthesizer is shared with the first secondary receiver, and wherein the second synthesizer is shared with the second secondary receiver.

11. The wireless communication device of claim 1, wherein the wireless communication device is configured to receive 4Rx multiple-input and multiple-output communications using the first antenna, the second antenna, the third antenna and the fourth antenna.

12. A method for receiving a multiple-input and multiple-output wireless signal, comprising:

receiving a first multiple-input and multiple-output wireless signal using a first antenna, wherein the first antenna is coupled to a transceiver chip;

routing the first multiple-input and multiple-output wireless signal through a first primary receiver on the transceiver chip to obtain a primary receive inphase/quadrature signal;

receiving a second multiple-input and multiple-output wireless signal using a second antenna, wherein the second antenna is coupled to the transceiver chip, and wherein the second antenna is a wireless local area network antenna;

routing the second multiple-input and multiple-output wireless signal through a first secondary receiver on the transceiver chip to obtain a secondary receive inphase/quadrature signal;

receiving a third multiple-input and multiple-output wireless signal using a third antenna, wherein the third antenna is coupled to a receiver chip;

routing the third multiple-input and multiple-output wireless signal through a second primary receiver on the receiver chip to obtain a tertiary receive inphase/quadrature signal;

18

receiving a fourth multiple-input and multiple-output wireless signal using a fourth antenna, wherein the fourth antenna is coupled to the receiver chip, and wherein the fourth antenna is a global position system antenna; and routing the fourth multiple-input and multiple-output wireless signal through a second secondary receiver on the receiver chip to obtain a quaternary receive inphase/quadrature signal, wherein the first primary receiver, the second primary receiver, the first secondary receiver and the second secondary receiver are configured for both carrier aggregation operation and multiple-input and multiple-output operation.

13. The method of claim 12, further comprising obtaining a receive signal from the primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive inphase/quadrature signal.

14. The method of claim 13, wherein the primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive inphase/quadrature signal are passed through a baseband digital modem to obtain the receive signal.

15. The method of claim 12, wherein the method is performed by a wireless communication device.

16. The method of claim 15, wherein the wireless communication device comprises:

a first multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:

the first antenna;

the second antenna; and

the transceiver chip, wherein the first multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a first carrier aggregation receiver path; and

a second multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:

the third antenna;

the fourth antenna; and

the receiver chip, wherein the second multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a second carrier aggregation receiver path.

17. The method of claim 16, wherein the wireless communication device does not require a power splitter, an external low noise amplifier or die-to-die signal routing.

18. The method of claim 16, wherein the transceiver chip comprises:

a transmitter,

wherein each receiver comprises multiple low noise amplifiers.

19. The method of claim 18, wherein a first routing is used from the first antenna through the first primary receiver to obtain a primary receive inphase/quadrature signal, wherein a second routing is used from the second antenna through the first secondary receiver to obtain a secondary receive inphase/quadrature signal, wherein a third routing is used from the third antenna through the second primary receiver to obtain a tertiary receive inphase/quadrature signal, and wherein a fourth routing is used from the fourth antenna through the second secondary receiver to obtain a quaternary receive inphase/quadrature signal.

20. The method of claim 19, wherein the first routing passes through a duplexer and through a low noise amplifier on the first primary receiver.

## 19

21. The method of claim 19, wherein the second routing passes through a surface acoustic wave filter and through a low noise amplifier on the first secondary receiver.

22. The method of claim 19, wherein the third routing passes through a surface acoustic wave filter and through a low noise amplifier on the second primary receiver.

23. The method of claim 19, wherein the fourth routing passes through a surface acoustic wave filter and through a low noise amplifier on the second secondary receiver.

24. The method of claim 16, wherein only two synthesizers are running on the wireless communication device when the wireless communication device is receiving multiple-input and multiple-output communications.

25. The method of claim 24, wherein the first primary receiver comprises a first synthesizer, wherein the second primary receiver comprises a second synthesizer, wherein the first synthesizer is shared with the first secondary receiver, and wherein the second synthesizer is shared with the second secondary receiver.

26. The method of claim 16, wherein the wireless communication device is configured to receive 4Rx multiple-input and multiple-output communications using the first antenna, the second antenna, the third antenna and the fourth antenna.

27. An apparatus for receiving a multiple-input and multiple-output wireless signal, comprising:

means for receiving a first multiple-input and multiple-output wireless signal using a first antenna, wherein the first antenna is coupled to a transceiver chip;

means for routing the first multiple-input and multiple-output wireless signal through a first primary receiver on the transceiver chip to obtain a primary receive inphase/quadrature signal;

means for receiving a second multiple-input and multiple-output wireless signal using a second antenna, wherein the second antenna is coupled to the transceiver chip, and wherein the second antenna is a wireless local area network antenna;

means for routing the second multiple-input and multiple-output wireless signal through a first secondary receiver on the transceiver chip to obtain a secondary receive inphase/quadrature signal;

means for receiving a third multiple-input and multiple-output wireless signal using a third antenna, wherein the third antenna is coupled to a receiver chip;

means for routing the third multiple-input and multiple-output wireless signal through a second primary receiver on the receiver chip to obtain a tertiary receive inphase/quadrature signal;

## 20

means for receiving a fourth multiple-input and multiple-output wireless signal using a fourth antenna, wherein the fourth antenna is coupled to the receiver chip, and wherein the fourth antenna is a global position system antenna; and

means for routing the fourth multiple-input and multiple-output wireless signal through a second secondary receiver on the receiver chip to obtain a quaternary receive inphase/quadrature signal, wherein the first primary receiver, the second primary receiver, the first secondary receiver and the second secondary receiver are configured for both carrier aggregation operation and multiple-input and multiple-output operation.

28. The apparatus of claim 27, further comprising obtaining a receive signal from the primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive inphase/quadrature signal.

29. The apparatus of claim 28, wherein the primary receive inphase/quadrature signal, the secondary receive inphase/quadrature signal, the tertiary receive inphase/quadrature signal and the quaternary receive inphase/quadrature signal are passed through a baseband digital modem to obtain the receive signal.

30. The apparatus of claim 27, wherein the apparatus is a wireless communication device.

31. The apparatus of claim 30, wherein the wireless communication device comprises:

a first multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:  
the first antenna;  
the second antenna; and  
the transceiver chip, wherein the first multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a first carrier aggregation receiver path; and

a second multiple-input and multiple-output carrier aggregation receiver reuse architecture that comprises:  
the third antenna;  
the fourth antenna; and  
the receiver chip, wherein the second multiple-input and multiple-output carrier aggregation receiver reuse architecture reuses a second carrier aggregation receiver path.

\* \* \* \* \*