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(54) **METHOD AND APPARATUS FOR TUNING A COMMUNICATION DEVICE FOR MULTI BAND OPERATION**

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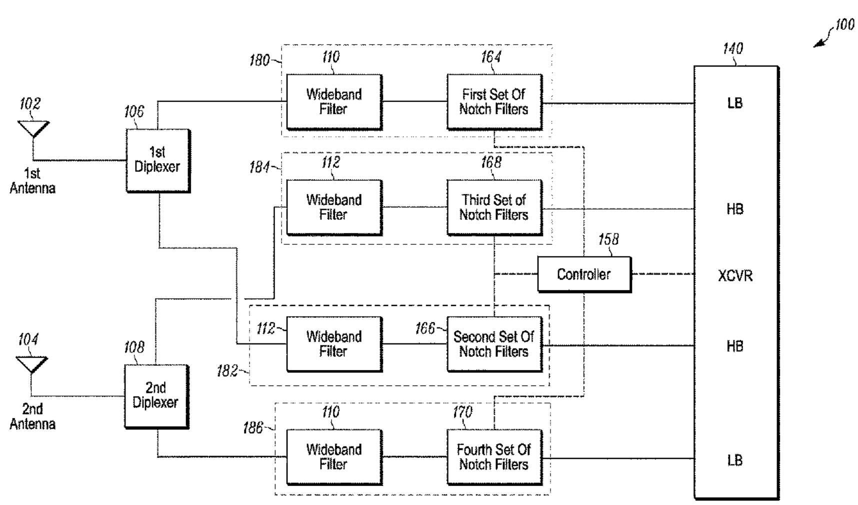
(57) **ABSTRACT**

In one example, a wireless communication device adapted for multi-band operation includes a first antenna, a first diplexer configured to pass signals within first and second sets of frequency bands, first and second signal paths, wherein each signal path includes a set of notch filters tunable to attenuate a different frequency. The wireless communication device includes a second antenna, a second diplexer configured to pass the first and second frequency bands, third and fourth signal paths, wherein each of the third and fourth signal paths includes one or more notch filters tunable to attenuate a different frequency, and a transceiver coupled to each signal path.

20 Claims, 6 Drawing Sheets



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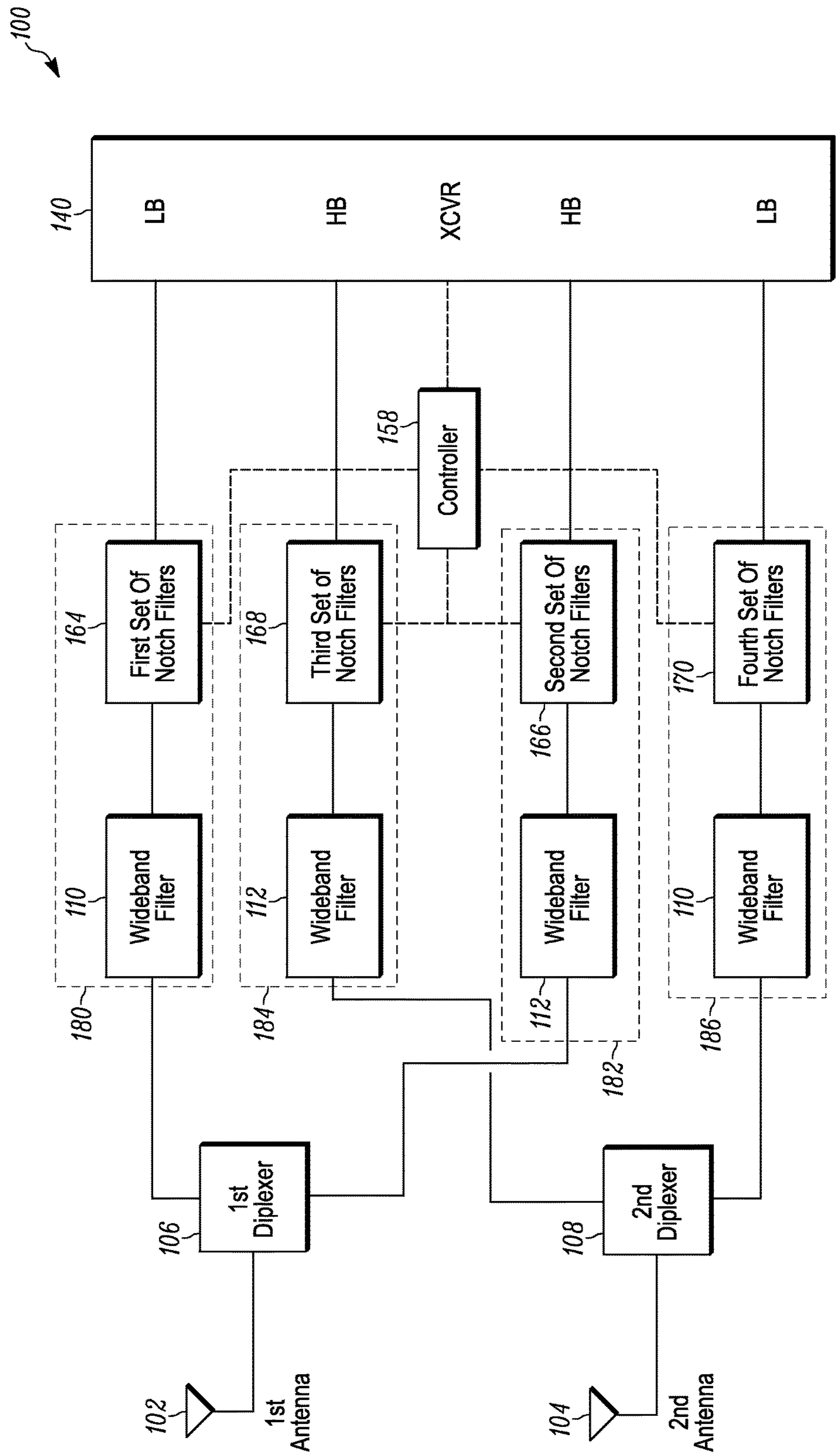
100
140
LB
HB
XCVR
HB
LB
158
Controller
164
First Set Of Notch Filters
168
Third Set of Notch Filters
Second Set Of Notch Filters
166
170
Fourth Set Of Notch Filters
110
Wideband Filter
112
Wideband Filter
Wideband Filter
112
110
Wideband Filter
180
184
182
186
1st Diplexer
106
2nd Diplexer
108
102
1st Antenna
104
2nd Antenna

FIG. 1

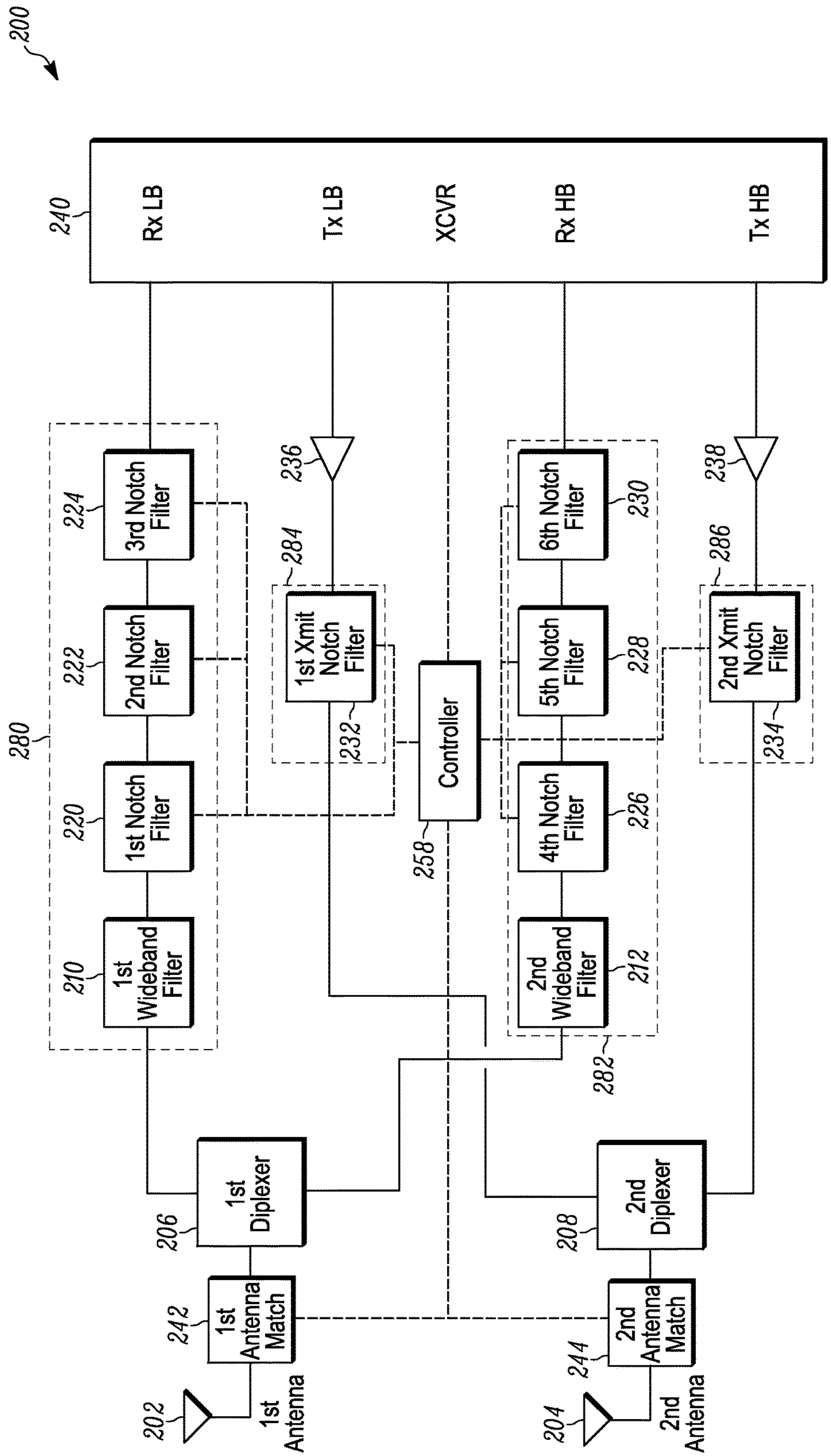
200
240
Rx LB
Tx LB
XCVR
Rx HB
Tx HB
236
238
280
224
3rd Notch Filter
222
2nd Notch Filter
220
1st Notch Filter
210
1st Wideband Filter
284
1st Xmit Notch Filter
232
Controller
258
6th Notch Filter
230
5th Notch Filter
228
4th Notch Filter
226
2nd Wideband Filter
212
282
286
2nd Xmit Notch Filter
234
1st Diplexer
206
2nd Diplexer
208
242
1st Antenna Match
244
2nd Antenna Match
202
1st Antenna
204
2nd Antenna

FIG. 2

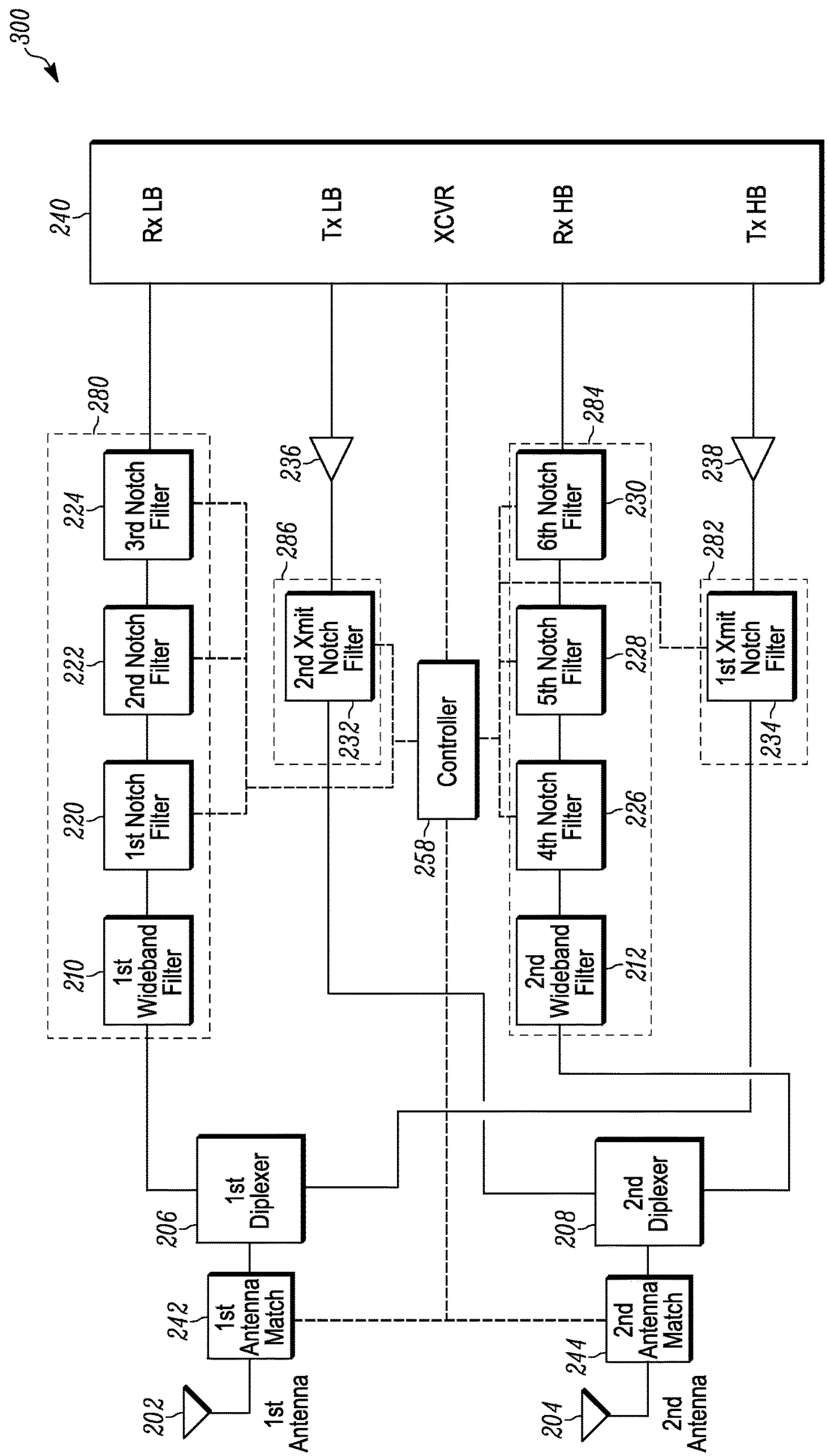
300
240
Rx LB
Tx LB
XCVR
Rx HB
Tx HB
280
284
236
238
224
3rd Notch Filter
230
6th Notch Filter
286
282
222
2nd Notch Filter
2nd Xmit Notch Filter
Controller
5th Notch Filter
228
1st Xmit Notch Filter
232
234
220
1st Notch Filter
258
4th Notch Filter
226
210
1st Wideband Filter
2nd Wideband Filter
212
1st Diplexer
206
2nd Diplexer
208
242
1st Antenna Match
2nd Antenna Match
244
202
1st Antenna
204
2nd Antenna

FIG. 3

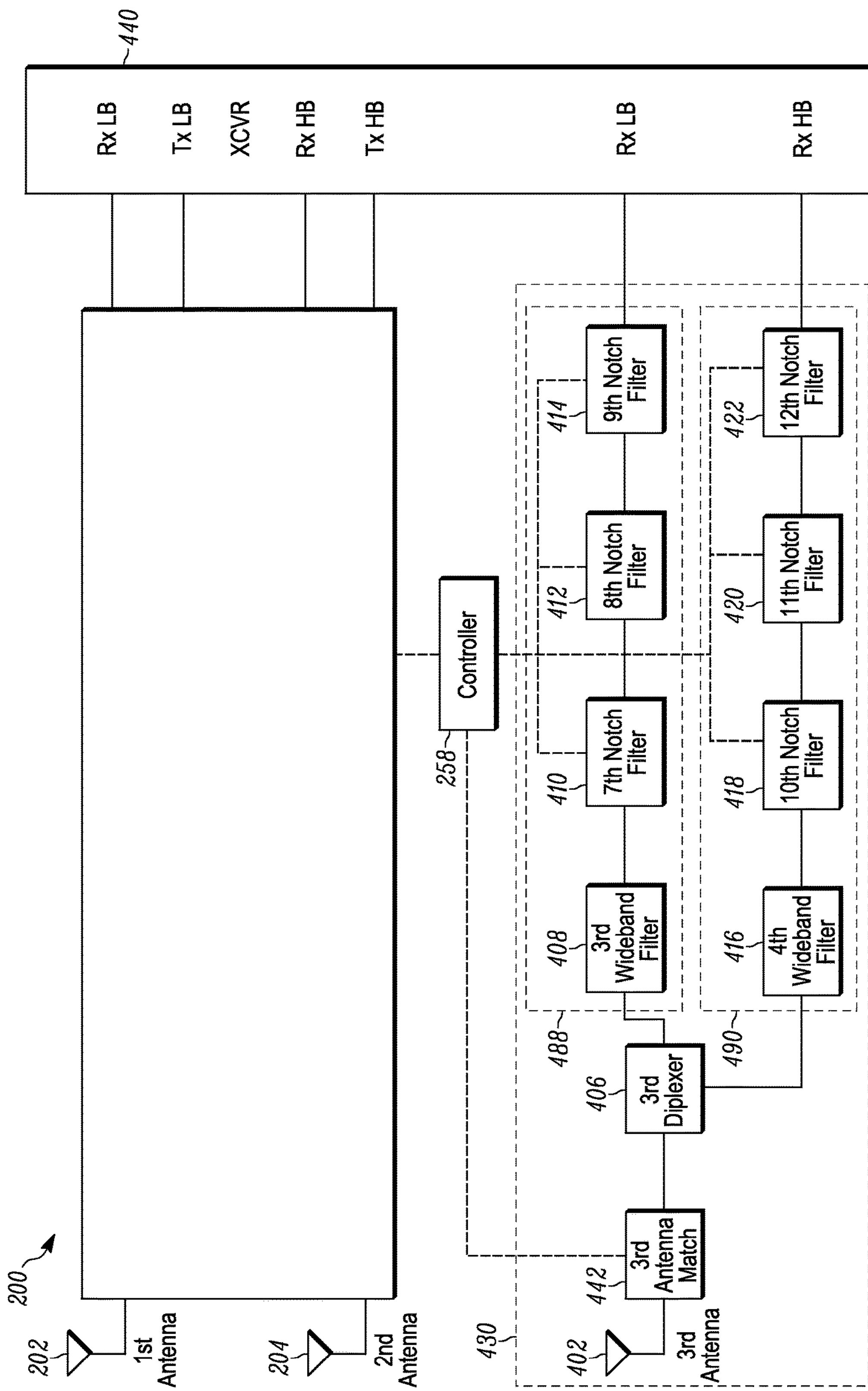
440
Rx LB
Tx LB
XCVR
Rx HB
Tx HB
Rx LB
Rx HB
Controller
258
9th Notch Filter
414
8th Notch Filter
412
7th Notch Filter
410
3rd Wideband Filter
408
12th Notch Filter
422
11th Notch Filter
420
10th Notch Filter
418
4th Wideband Filter
416
488
490
3rd Diplexer
406
3rd Antenna Match
442
200
202
1st Antenna
204
2nd Antenna
430
402
3rd Antenna
400

FIG. 4

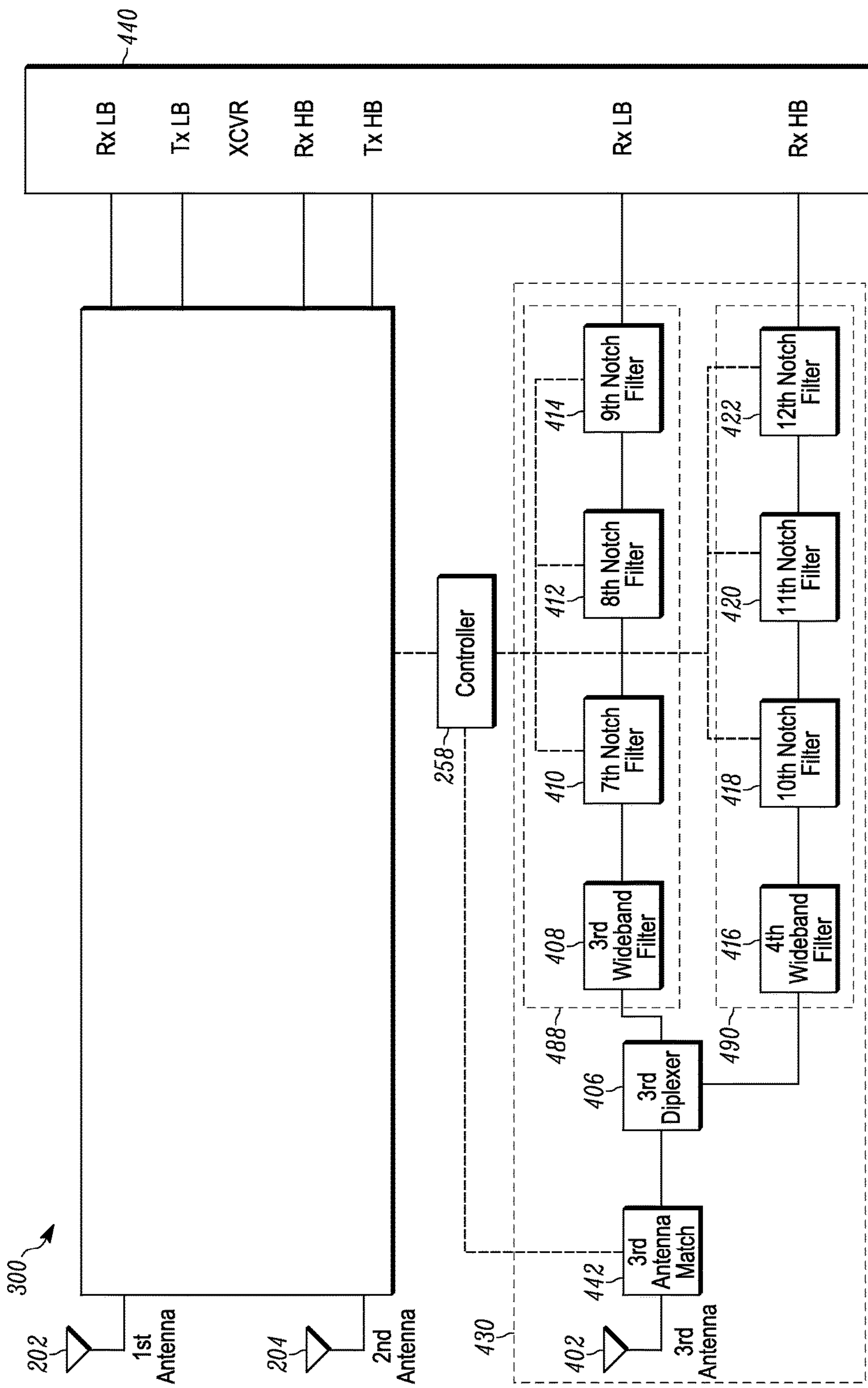
440
Rx LB
Tx LB
XCVR
Rx HB
Tx HB
Rx LB
Rx HB
300
202
1st Antenna
204
2nd Antenna
258
Controller
430
402
3rd Antenna
442
3rd Antenna Match
406
3rd Diplexer
488
490
408
3rd Wideband Filter
410
7th Notch Filter
412
8th Notch Filter
414
9th Notch Filter
416
4th Wideband Filter
418
10th Notch Filter
420
11th Notch Filter
422
12th Notch Filter
500

FIG. 5

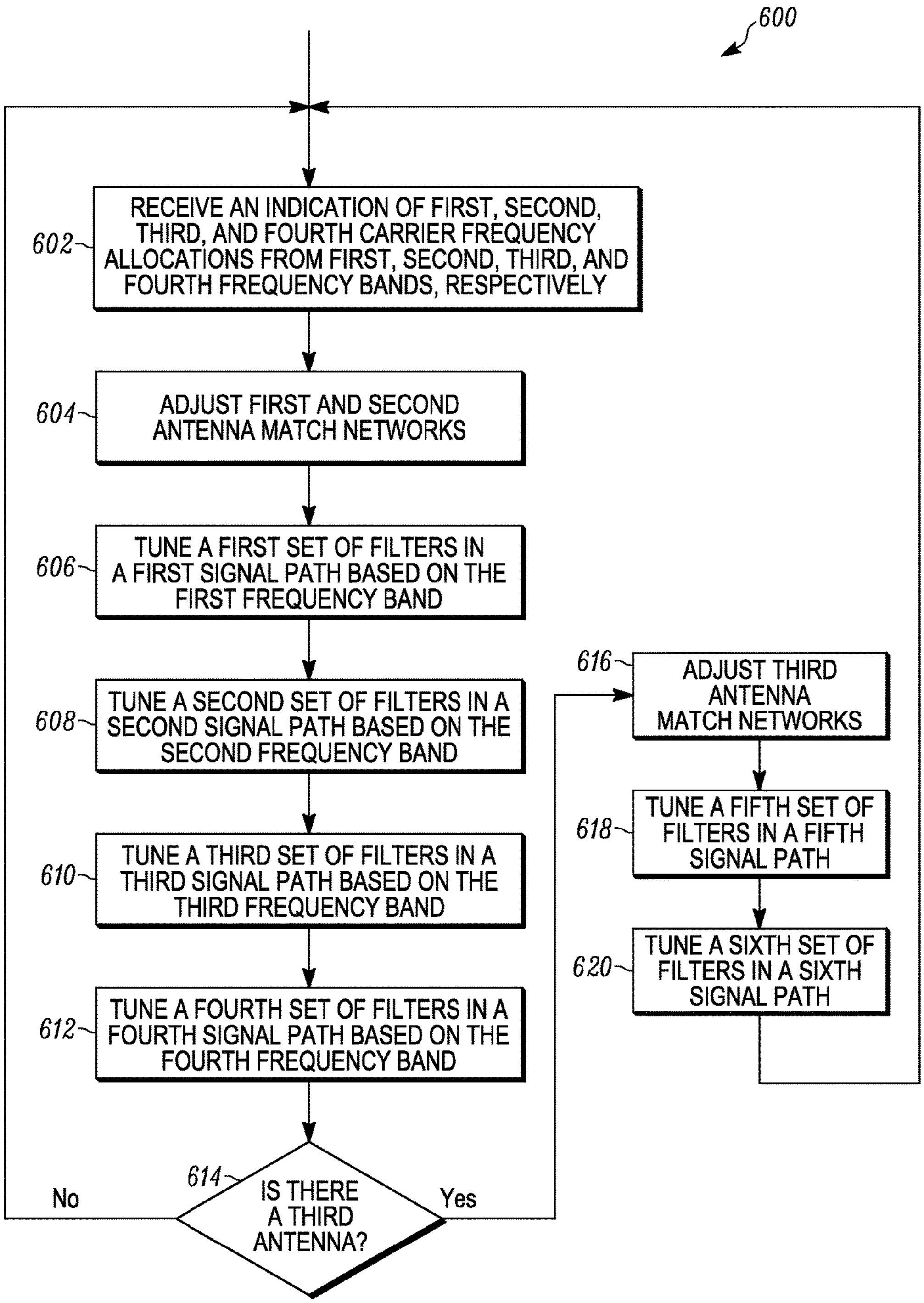
600
602
RECEIVE AN INDICATION OF FIRST, SECOND, THIRD, AND FOURTH CARRIER FREQUENCY ALLOCATIONS FROM FIRST, SECOND, THIRD, AND FOURTH FREQUENCY BANDS, RESPECTIVELY
604
ADJUST FIRST AND SECOND ANTENNA MATCH NETWORKS
606
TUNE A FIRST SET OF FILTERS IN A FIRST SIGNAL PATH BASED ON THE FIRST FREQUENCY BAND
608
TUNE A SECOND SET OF FILTERS IN A SECOND SIGNAL PATH BASED ON THE SECOND FREQUENCY BAND
610
TUNE A THIRD SET OF FILTERS IN A THIRD SIGNAL PATH BASED ON THE THIRD FREQUENCY BAND
612
TUNE A FOURTH SET OF FILTERS IN A FOURTH SIGNAL PATH BASED ON THE FOURTH FREQUENCY BAND
614
IS THERE A THIRD ANTENNA?
No
Yes
616
ADJUST THIRD ANTENNA MATCH NETWORKS
618
TUNE A FIFTH SET OF FILTERS IN A FIFTH SIGNAL PATH
620
TUNE A SIXTH SET OF FILTERS IN A SIXTH SIGNAL PATH

FIG. 6

METHOD AND APPARATUS FOR TUNING A COMMUNICATION DEVICE FOR MULTI BAND OPERATION

FIELD OF THE DISCLOSURE

The present disclosure relates generally to wireless communications and more particularly to a method and apparatus for tuning a communication device for multiband operation.

BACKGROUND

Communication devices are being designed to transmit and receive in multiple frequency bands, also referred to herein as multiband operation, to take advantage of techniques such as transmit and receive diversity and carrier aggregation. However, the current design approaches for multiband operation have some shortcomings. For example, in one conventional radio architecture design approach, as the number of active frequency bands increases, the number of dedicated paths between a transceiver and antennas and, hence, the number of components needed for the radio to operate in multiple frequency bands, with or without carrier aggregation, quickly becomes impractical. An alternative cognitive design approach uses fewer dedicated paths and components but requires unreasonable levels of isolation and attenuation from the components.

BRIEF DESCRIPTION OF THE FIGURES

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate embodiments of concepts that include the claimed invention, and explain various principles and advantages of those embodiments.

FIG. **1** is a block diagram of a wireless communication device architecture in accordance with some embodiments.

FIG. **2** is a block diagram of another wireless communication device architecture in accordance with some embodiments.

FIG. **3** is a block diagram of still another wireless communication device architecture in accordance with some embodiments.

FIG. **4** is a block diagram of yet another wireless communication device architecture in accordance with some embodiments.

FIG. **5** is a block diagram of another wireless communication device architecture in accordance with some embodiments.

FIG. **6** is a flowchart of a method of tuning a wireless communication device for multiband operation in accordance with some embodiments.

Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of embodiments of the present invention.

The apparatus and method components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments of the present invention so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein.

DETAILED DESCRIPTION

Generally speaking, pursuant to the various embodiments, the present disclosure provides for a wireless communication device adapted for multiband operation. The wireless communication device includes multiple antennas. Each antenna is coupled, through a diplexer, to a first signal path that communicates signals over frequencies selected from a set (e.g., a plurality) of high frequency bands and to a second signal path that communicates signals over frequencies selected from a set (e.g., a plurality) of low frequency bands. Each signal path includes a set of notch filters. Within each set of notch filters, each notch filter is tunable to attenuate a different blocker frequency. A controller coupled to the notch filters performs a method to tune the notch filters, in general, based on a plurality of operating frequency bands and, more specifically, based on a plurality of operating frequencies allocated from the plurality of operating frequency bands. Moreover, at least some of the signal paths are receive paths, wherein the wireless communication device further includes a wideband filter within each receive path, wherein half of the wideband filters are configured to filter frequencies outside of the set of low frequency bands, and the other half of the wideband filters are configured to filter frequencies outside of the set of high frequency bands.

Accordingly, using the present teachings, a wireless communication device design is provided that enables simultaneous operation in multiple frequency bands for both transmit and receive diversity and carrier aggregation. This can be accomplished while minimizing the number of dedicated signal paths and components needed in the wireless communication device and while eliminating the need for unrealistically high performance components, for instance, in terms of attenuation and isolation requirements.

Referring now to the drawings, and in particular to FIG. **1**, in which is shown a wireless communication device **100** that is adapted for multi-band operation in accordance with embodiments of the present teachings. Multi-band operation means that the wireless communication device is operable over a plurality of frequency bands. In general, as used herein, devices such as wireless communication device **100** being "configured," "operative" or "adapted" means that such devices are implemented using one or more hardware devices such as memory devices, network interfaces such as transceivers, and/or processors that are operatively coupled, for example, as is shown in FIGS. **1-5**. The memory devices, network interfaces, and/or processors, when programmed (e.g., using software or firmware), form the means for these system elements to implement their desired functionality, for example, as illustrated by reference to the method shown in FIG. **6**.

The wireless communication device **100**, in one example, is a radio telephone, a tablet computer, a personal digital assistant, a gaming console, a remote controller, an electronic book reader, or any other type of electronic device capable of communicating in conformance with various wireless standards including, but not limited to, 3rd Generation Partnership Project (3GPP) standards, including Long Term Evolution (LTE), LTE advanced, High Speed Packet Access+(HSPA), and the like. Those skilled in the art, however, will recognize and appreciate that the specifics of this example are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings. For example, since the teachings described do not depend on the particular device within which the teachings are implemented or the wireless access protocols used, the teachings can be applied to any type of electronic device capable of communicating signals using any suitable wireless access protocols, although a wireless communication device **100** is shown for illustrative purposes. As such, other alternative implementations using different types of devices, including infrastructure devices such as base stations, and different wireless access protocols are contemplated and are within the scope of the various teachings described.

As shown, the wireless communication device **100** includes: a first antenna **102**; a first diplexer **106** coupled to the first antenna **102** and configured to pass signals within a first set of frequency bands and a second set of frequency bands; and first and second signal paths **180**, **182** coupled to the first diplexer **106**, wherein each signal path **180**, **182** includes a set of notch filters **164**, **166**, respectively, and each signal path **180**, **182** is configured to communicate signals within a different one of the first and second sets of frequency bands. The wireless communication device **100** also includes: a second antenna **104**; a second diplexer **108** coupled to the second antenna **104** and configured to pass signals within the first and second sets of frequency bands; and third and fourth signal paths **184**, **186** coupled to the second diplexer **108**, wherein each of the third and fourth signal paths **184**, **186** includes a set of notch filters **168**, **170**, and each of the third and fourth signal paths **184**, **186** is configured to communicate signals within a different one of the first and second sets of frequency bands. Furthermore, the wireless communication device **100** includes a transceiver **140** coupled to each signal path **180-186** and a controller **158** coupled to the transceiver **140** and to the sets of notch filters **164-170**.

In addition, the wireless communication device **100** includes: a first wideband filter **110** configured to filter frequencies outside of the first set of frequency bands: and a second wideband filter **112** configured to filter frequencies outside of the second set of frequency bands. Each wideband filter **110**, **112** is coupled to at least one of the first or the second diplexers **106**, **108** and coupled within a different signal path. As shown in FIG. **1** and similarly in FIGS. **2-5**, a solid line coupling two or more elements or components represents a signal line capable of carrying analog signals and/or digital data streams including voice, data or other payload, for instance. Whereas, a dashed line coupling two or more elements or components represents a control line used for communicating control signals between, in most circumstances, a controller, such as controller **158**, and other elements comprising the illustrated wireless communication device.

In an embodiment, the signal paths **180-186** comprise: two transmit paths that send signals having data to the antennas **102** and **104** for transmission to other devices and two receive paths that receive signals having data from other devices via the antennas **102** and **104**. In an embodiment, one of the transmit paths is a high frequency band (high band) path connected to a high band (HB) port of the transceiver **140**, and one of the transmit paths is a low frequency band (low band) path connected to a low band (LB) port of the transceiver **140**. In one embodiment, the low band includes a first plurality of frequency bands; and the high band includes a second plurality of frequency bands, wherein at least some of the frequency bands in the low band include lower spectrum frequencies than the frequency bands in the high band.

In one example, transition bands (which are not used for communications purposes) separate the low and high frequency bands. A wide transition band enables low loss in the diplexers **106**, **108**. In one embodiment, a single transition band separates the low band and high band. In a particular embodiment, the low band can include 3GPP bands 12 (uplink 698-716 MHz, downlink 728-746 MHz), 17 (uplink 704-716 MHz, downlink 734-746), 13 (uplink 777-787 MHz, downlink 746-756 MHz), 20 (uplink 832-862 MHz, downlink 791-821 MHz), 5 (uplink 824-849 MHz, downlink 869-894 MHz), 8 (uplink 880-915 MHz, downlink 925-960 MHz), and other bands within the range of frequencies between the lower end of 3GPP band 12 (699 MHz), and the upper end of the 3GPP band 8 (960 MHz). The high band can include 3GPP bands 3 (uplink 1710-1785 MHz, downlink 1805-1880 MHz), 4 (uplink 1710-1755 MHz, downlink 2110-2155 MHz), 2 (uplink 1850-1910 MHz, downlink 1930-1990 MHz), 1 (uplink 1920-1980 MHz, downlink 2110-2170 MHz), 7 (uplink 2500-2570 MHz, downlink 2620-2690 MHz), 41 (2496-2690 MHz) and other bands within the range of frequencies between the lower end of 3GPP band 3 (1710 MHz), and the upper end of the 3GPP band 41 (2690 MHz). In this embodiment, the transition band is between the highest frequency of band 8 (960 MHz), and the lowest frequency of band 3 (1710 MHz). These frequency bands are provided for the purposes of illustration. In other embodiments, other frequency bands are included in the low and high frequency bands. Also, a frequency band that is included in the low band in this embodiment is included in the high band of another embodiment, and a frequency band that is included in the high band of this embodiment is included in the low band of another embodiment.

Similarly, one of the receive paths is a high band path connected to a HB port of the transceiver **140**, and one of the receive paths is a low band path connected to a LB port of the transceiver **140**. Moreover, in accordance with the present teachings, each diplexer **106** and **108** is connected to both a high band path and a low band path. Whether these two signal paths are transmit or receive paths depends on the particular device architecture, examples of which are shown in FIGS. **2-5**. The diplexers function as dual passband filters to attenuate or block frequencies outside of two distinct ranges of frequencies and to pass, meaning to allow through, frequencies within the two distinct ranges of frequencies. In the present example, the two distinct ranges of frequencies comprise a high band and a low band. Also, to attenuate or filter means to diminish the intensity or strength of certain frequency components of a signal to the point of, in one example, blocking those frequency components.

In addition to the set of notch filters, the two receive paths include a wideband filter, which is a single passband filter, coupled between the set of notch filters and the diplexer. Accordingly one wideband filter **110** attenuates or blocks frequencies outside of the first range of frequencies and passes frequencies within the first range of frequencies, e.g., the low band. The other wideband filter **112** attenuates or blocks frequencies outside of the second range of frequencies and passes frequencies within the second range of frequencies, e.g., the high band. By contrast, the notch filters are tunable to attenuate certain frequencies, referred to herein as blocking signals, or blockers, and having frequencies referred to herein as interfering frequencies, blocking signal frequencies or blocker frequencies. Blocking signals can cause an increase in the minimum power level of desired signals that can be received or detected by the transceiver **140**, referred to herein as the sensitivity level, or sensitivity.

The reduction in the sensitivity due to coupling of interfering signals into the transceiver **140** is referred to herein as "blocking", "desensitization", or "desense". Blocking signals can be transmit signals coupled from the transceiver **140**, interference signals coupled from the first or second antenna **102**, **104**, or from signal or noise sources within or external to communication device **100**. Importantly, blocking signals can be caused by intermodulation (IM) of interference signals and/or transmit signals.

The following blocker frequencies can be particularly problematic, listed in order of frequency from lowest to highest, where RX denotes the receive frequency and TX denotes the transmit frequency: a) "3^{rd} order mix up": |TX−RX|/2; b) "2^{nd} order mix up": |TX−RX|; c) "Receive divided by 3": RX/3; d) "Receive divided by 2": RX/2; e) "Duplex Image" or "Image": 2TX−RX; f) "Half Duplex": (TX+RX)/2; g) "2^{nd} order mix down": (TX+RX); h) "3^{rd} order mix down": 2TX+RX. Blocking signals caused by intermodulation of signals are referred to herein as intermodulation blockers. The "duplex image" and "half duplex" blocking signals can be especially problematic, since these occur closest to the receive frequency and may be difficult or impossible to attenuate with fixed or broadband filtering, such as wideband filters **110**, **112**. Notch filters **164-170** can be employed to attenuate blocking signals having interfering frequencies that are outside of the range of frequencies attenuated by the wideband filters.

In an embodiment according to the present teachings, the notch filters are tunable by the controller **158** based on a frequency band of operation for the transmitter or receiver connected to the signal path containing the notch filters. In a more specification embodiment, the notch filters are tunable by the controller **158** based on a carrier frequency of operation for the transmitter or receiver connected to the signal path containing the notch filters. For example, the notch filters **164-170** can provide low insertion loss in a receive band and attenuation at: a duplex image frequency being two times a transmit frequency minus a receive frequency; and at a half-duplex frequency being the sum of the transmit and receive frequencies divided by two. The notch filter can provide additional filtering, such as other blocker signal frequencies described above and other useful filtering.

FIG. **1** shows possible locations (as indicated by the dashed boxes) of the wideband filters **110**, **112** within the first, second, third, and fourth signal paths. The actual placement of the wideband filters depends on the particular device **100** architecture, wherein example wireless communication device architectures are illustrated in and described by reference to FIGS. **2-5**. Thus, depending on the embodiment, the first diplexer **106** is coupled to one, both or none of the first and second wideband filters **110**, **112**. Also, depending on the embodiment, the second diplexer **108** is also coupled to one, both or none of the first and second diplexers **106**, **108**.

As used herein, a signal path is a path that communicates signals between a transceiver and an antenna and that includes at least one filter component and at least one signal line between the filter components. A receive path extends between an antenna and a receive port of a transceiver. A transmit path extends between a transmit port of the transceiver and an antenna. A signal is a waveform (such as a radio wave) that carries a data stream, and a data stream is a sequence of digitally encoded data units (such as data packets containing data), which is used to transmit or receive information. A frequency band represents a range of frequencies from which channel or frequency allocation occurs for communicating, meaning transmitting and receiving, signals. A transmit frequency band is used for allocating channels having transmit carrier frequencies, and a receive frequency band is used for allocating channels having receive carrier frequencies. An operating frequency band is an active frequency band from which channels having active transmit and/or receive frequencies of operation are currently allocated to an electronic device for communicating data. A channel is the logical representation of radio frequency (RF) resources carrying data streams; and the channel is characterized by a transmit (carrier) frequency for transmitting data or a receive (carrier) frequency for receiving data and a capacity.

Turning again to the components of wireless communication device **100**, controller **158**, in one embodiment, is a baseband processor **158**. For example, the controller **158** is comprised of one or more integrated circuit chips having data processing hardware, a memory (e.g., random access memory (RAM)) and firmware or software used to configure, e.g., program, the controller **158** to perform a number of radio control functions that require an antenna for data communications. The functions include, but are not limited to: encoding and decoding digital data; generating or parsing out certain control data such as acknowledges (ACKs), not-acknowledges (NACKs), channel quality indicators (CQIs), etc.; receiving indications of channel allocation from the network and/or applications within the device **100** and, responsively, providing frequency band selection to the transceiver; antenna match control; and notch filter tuning control. In an embodiment, the controller is coupled to the notch filters in the first, second, third, and fourth signal paths, wherein the controller is configured to tune the notch filters depending a set of frequency bands of operation within at least one of the first (e.g., low) or the second (e.g., high) frequency bands. In a further embodiment, the controller is configured to tune the notch filters depending on a set of allocated carrier frequencies of operation within at least one of the first or the second set of frequency bands.

During a transmit operation, the controller **158** receives data, for instance, audio (e.g., voice) data from a microphone, video data from a recording device, or other data from an application in the device **100**. The controller **158** supplies a digital information signal containing the data, also referred herein as a data stream, to one or more transmitters in the transceiver **140**. The controller **158** also supplies to the one or more transmitters an indication of one or more frequency bands of operation depending on the one or more transmit frequencies of the one or more channels allocated to transmit the data. Each transmitter modulates the data stream onto a carrier signal at the corresponding transmit frequency and provides the modulated signal to a transmit port, which is connected to a transmit path for transmission to another device by the antenna **102** and/or antenna **104**.

During a receive operation the reverse signal processing is performed. The antenna **102** and/or **104** receives (i.e., picks up) a signal having a data stream, which is processed by components in a receive path to remove unwanted frequency components from the signal before the signal is passed to one or more receive ports of the transceiver **140**. One or more receivers within the transceiver **140** demodulate the signal, and the controller **158** decodes the demodulated data to enable other components in the device **100**, for instance, to prepare the received data for storage and/or presentation to a user. The controller **158** also supplies to the one or more receivers an indication of one or more frequency bands of operation depending on the one or more receive frequencies of the one or more channels allocated to receive the data.

In an embodiment, the transceiver **140** has at least two transmitters and at least two receivers, each configured to operate within a particular frequency range, which comprises a set of frequency bands. In one embodiment, one transmitter is configured to operate over a first distinct plurality of frequency bands, such as a plurality of low bands. Another transmitter is configured to operate over a second distinct plurality of frequency bands, such as a plurality of high bands. One receiver is configured to operate over the plurality of low bands, and another receiver is configured to operate over the plurality of high bands.

Using the above-described architecture, the wireless communication device **100** of FIG. **1** is configured, in an example implementation, to communicate signals in multiple frequency bands at the same time. In one example, each signal path can communicate a signal using a different channel allocated from of a different frequency band or the same frequency bands. Thus, having four signal paths, the communication device **100** is configured to communicate signals in a maximum of four different frequency bands over a maximum of four different channels at the same time to implement diversity and/or carrier aggregation techniques. Adding additional signal paths enables the use of additional different frequency bands simultaneously and further optimized use of diversity and/or carrier aggregation techniques. Further, signal paths **180**, **182** and signal paths **184**, **186** are each coupled to a single antenna as opposed to each signal path **180**, **182**, **184**, **186** being coupled to its own antenna, as in some prior art architectures. Therefore, space is saved over those prior art configurations that require separate antennas and signal paths for each set of frequency bands that the wireless communication device **100** supports. FIGS. **2-5** shows some particular wireless communication device architectures that are derivable from architecture **100**.

FIG. **2** shows one embodiment of a wireless communication device architecture **200** in accordance with the present teachings. Device **200** includes a first antenna **202** that is configured to receive signals and a second antenna **204** that is configured to transmit signals. More particularly, the first antenna **202** is coupled to a first diplexer **206** using a first antenna match network **242**; and the second antenna **204** is coupled to a second diplexer **208** using a second antenna match network **244**. The first and second antenna match networks are adjusted, in one embodiment by a controller **258** coupled to the antenna match networks **242**, **244**, based on the operating frequency band in order to match an impedance seen at the antenna with an impedance at the transmitter or receiver coupled to the antenna. The device **200** further comprises first and second wideband filters **210**, **212**, respectively, that are both coupled to the first diplexer **206**. Additionally, the first diplexer **206** is coupled to a first signal path **280** and a second signal path **282**; and the second diplexer **208** is coupled to a third signal path **284** and a fourth signal path **286**. The first, second, third and fourth signal paths are coupled to a transceiver **240**, and the transceiver **240** is coupled to the controller **158**.

In the embodiment shown, the wireless communication device **200** is configured such that the first signal path **280** comprises a first receive path; the second signal path **282** comprises a second receive path; the third signal path **284** comprises a first transmit path; and the fourth signal path **286** comprises a second transmit path **286**. Accordingly, the first receive path **280** is coupled to a first receive port of the transceiver **240**, which in this implementation is a LB receive port. The second receive path **282** is coupled to a second receive port of the transceiver **240**, which in this implementation is a HB receive port. The first transmit path **284** is coupled via a power amplifier **236** to a first transmit port of the transceiver **240**, which in this implementation is a LB transmit port. The second transmit path **286** is coupled via a power amplifier **238** to a second transmit port of the transceiver **240**, which in this implementation is a HB transmit port.

Further, the first receive path **280** is configured to communicate signals within the first set of frequency bands and includes the first wideband filter **210** and further includes a first notch filter **220**, a second notch filter **222**, and a third notch filter **224** each coupled to the controller **258** and tunable to attenuate a different frequency. Similarly, the second receive path **282** is configured to communicate signals within the second set of frequency bands and includes the second wideband filter **212** and further includes a fourth notch filter **226**, a fifth notch filter **228** and a sixth notch filter **230** each coupled to the controller **258** and tunable to attenuate a different frequency. The first transmit path **284** includes a first transmit notch filter **232** coupled to the controller **258**; and the second transmit path **286** includes a second transmit notch filter **234** coupled to the controller **258**. As can be seen, the receive paths and the transmit paths are coupled to different antennas. Nonetheless, depending on the operating or active frequency bands associated with each path, when transmit and receive paths are active at the same time (as is possible in these embodiments), the signals being communicated can create interfering frequencies, which are attenuated by the notch filters in the signal paths **280-286**.

For example, when the second antenna **204** transmits signals using the first transmit path **284** in the set of low frequency bands, undesired transmission leakage from the first transmit path **284** may mix with external interferers to create intermodulation blockers, half duplex blockers and image frequency blockers in the first receive path **280**, which is configured to receive signals in the set of low frequency bands. Similarly, when the second antenna **204** transmits in the set of high frequency bands, undesired transmission leakage from the second antenna **204** may mix with external interferers to create intermodulation blockers, half duplex blockers and image frequency blockers in the second receive path **282**, which is configured to receive signals in high frequency bands. Such blockers cause desense in the receive paths. Accordingly, to attenuate these blockers, the communication device **200**, in one embodiment, is configured such that, the first notch filter **220** is tunable to attenuate a first transmit frequency; the second notch **222** filter is tunable to attenuate a first half duplex blocker frequency; the third notch filter **224** is tunable to attenuate a first image blocker frequency; the fourth notch filter **226** is tunable to attenuate a second transmit frequency; the fifth notch filter **228** is tunable to attenuate a second half duplex blocker frequency; and the sixth notch filter **230** is tunable to attenuate a second image blocker frequency.

Moreover, transmissions from the LB transmit path **284** may cause noise in the LB receive path **280**. Similarly, transmissions from the HB transmit path **286** may cause noise in the HB receive path **282**. These undesirable signals may degrade the quality of the signal being received. Accordingly, the wireless communication device **200**, in this example embodiment, is configured such that: the first transmit notch filter **232** is tunable to attenuate receive frequencies in the first, e.g., LB, set of frequency bands.

Whereas, the second transmit notch filter **232** is tunable to attenuate receive frequencies in the second, e.g., HB, set of frequency bands.

Using the first antenna **202** for receiving signals and the second antenna **204** for transmitting signals creates isolation between the receive paths **280**, **282** and transmit paths **284**, **286**. This mitigates the amount of interference occurring in the receive paths due to transmission interference. Further, because the receive paths **280**, **282** and transmit paths **284**, **286** are isolated, the attenuation requirements of the diplexer **206** and filters comprising the receive paths **280**, **282** are lessened.

FIG. **3** shows one embodiment of a wireless communication device architecture **300** in which the first and second antennas **202**, **204** are each configured to receive and transmit signals. Architecture **300** is similar to architecture **200**, wherein the components are the same but the coupling of the signal paths **280-286** and with diplexers **242** and **242** is different. More particularly, the first diplexer **206** is coupled to a first signal path **280** and a second signal path **282**; and the second diplexer **208** is coupled to a third signal path **284** and a fourth signal path **286**. In accordance with this arrangement, the communication device **300** is configured such that the first signal path **280** comprises a first receive path **280**; the second signal path comprises a first transmit path **282**; the third signal path comprises a second receive path **284**; and the fourth signal path comprises a second transmit path **286**.

As the embodiment depicted in FIG. **3** shows, the communication device **300** is configured such that the first wideband filter **210** is coupled to the first diplexer **206** and included within the first receive path **280**, and second wideband filter **212** is coupled to the second diplexer **208** and included within the second receive path **284**. The first receive path **280** is configured to communicate signals within the first set of frequency bands and includes the first notch filter **220**, the second notch filter **222**, and the third notch filter **224** each tunable to attenuate a different frequency. The second receive path **284** is configured to communicate signals within the second set of frequency bands and includes the fourth notch filter **226**, the fifth notch filter **228** and the sixth notch filter **230** each tunable to attenuate a different frequency.

In FIG. **3**, the first antenna **102** is used for both transmitting and receiving signals, but the first receive path **280** is used only for receiving low frequency band signals and the first transmit path **282** is used only for transmitting high frequency band signals. Thus, the two signal paths **280**, **282** operate in two distinct sets of band groups. Similarly, the second antenna **204** includes receive path **284** and transmit path **286** which operate in two distinct sets of band groups. Because the first and second antennas **202**, **204** each support receive operations in one set of frequency bands and transmit operations in another set of frequency bands, the isolation that the diplexers **206**, **208** need to provide does not have to be as great as if the antennas **202**, **204** supported both transmit and receive operations in the same set of carrier frequency bands.

Some forms of carrier aggregation involve transmitting and receiving signals in more than one set of frequency bands. Because the antennas **202**, **204** each support transmission and receive operations in different sets of frequency bands, the embodiment depicted in FIG. **3** provides good support for this type of carrier aggregation.

FIG. **4** depicts an example embodiment of a wireless communication device architecture **400**. Architecture **400** incorporates architecture **200** (of FIG. **2**) having substantially the same components and functionality, except that the transceiver included in architecture **400** is labeled as **440** since it includes two additional receive ports, namely a second LB receive port and a second HB receive port.

The wireless communication device **400**, in this embodiment, further includes a third antenna path **430**. The third antenna path **430** includes: a third antenna **402**; and a third diplexer **406** coupled to the third antenna **402**, via a third antenna match network **442** that is coupled to the controller **258**. The third diplexer **406** is configured to pass signals within the first, e.g., LB, and the second, e.g., HB, sets of frequency bands. The third antenna path **430** further includes fifth and sixth signal paths **488** and **490**, respectively, coupled to the third diplexer **406** and to the transceiver **440**. The fifth signal path **488** comprise a third receive path, and the sixth signal path **490** comprises a fourth receive path **490**.

Each of the fifth and sixth signal paths **488** and **490** includes a set of notch filters, and each of the fifth and sixth signal paths **488**, **490** is configured to communicate signals within a different one of the first (LB) and second (HB) sets of frequency bands. The third antenna path **430** further includes a third wideband filter **408** coupled to the third diplexer **406** and included within the fifth signal path **488**, wherein the third wideband filter **408** is configured to filter frequencies outside of the first set of frequency bands. Moreover, The third antenna path **430** includes a fourth wideband filter **416** coupled to the third diplexer **406** and included within the sixth signal path **490**, wherein the fourth wideband filter **416** is configured to filter frequencies outside of the second set of frequency bands.

Just as the first signal path **280** may experience blockers when the second antenna **204** transmits, the fifth signal path **488**, which in this example is a third receive path, may similarly experience blockers. Also, the sixth signal path **490**, which in this example is a fourth receive path, may experience similar blockers as experienced by the second receive path **282**. Thus, in a further embodiment, the wireless communication device **400** is configured such that the third receive path **488** includes a seventh notch filter **410**, an eight notch filter **412**, and a ninth notch filter **414**, each coupled to the controller **258** and tunable to attenuate a different frequency, such as a first transmit frequency, a half duplex blocker frequency and an image blocker frequency. Similarly, the fourth receive path **490** includes a tenth notch filter **418**, an eleventh notch filter **420**, and a twelfth notch filter **422**, each coupled to the controller **258** and tunable to attenuate a different frequency, such as a second transmit frequency, a half duplex blocker frequency and an image blocker frequency.

The third antenna path **430**, in one example, is used to provide spatial diversity reception of signals. Spatial diversity involves receiving multiple copies of a transmitted signal and using the multiple copies of the signal to, for instance, correct transmission errors that have occurred. Thus, in one example, first antenna **202** and the third antenna **402** are tuned to receive signals from the same channels of the same frequency bands, and the transceiver **440** communicates the duplicate received signals to a baseband processor that recreates the originally transmitted signal.

FIG. **5** depicts a wireless communication device architecture **500**. Architecture **500** incorporates architecture **300** (of FIG. **3**) having substantially the same components and functionality, except that the transceiver included in architecture **500** is labeled as **440** since it includes two additional receive ports, namely a second LB receive port and a second HB receive port. Architecture **500** further incorporates the third antenna path **430** (of FIG. **4**) having substantially the same components and functionality.

We now turn to a detailed description of the functionality of the wireless communication device **100-500** elements in accordance with teachings herein and by reference to the remaining figure, FIG. **6**. FIG. **6** is a logical flowchart illustrating methods performed in an electronic device, such as a communication device **100-500** for tuning the communication device for multiband operation. In one embodiment, the wireless communication device is tuned in response to channel assignments communicated from a network to the wireless communication device. In one general example, a baseband processor, for example the controller **258**, receives the channel assignments, which initiates the tuning of at least one set of notch filters in accordance with the channel assignments. Thus, in one embodiment, at least some of the functionality illustrated by reference to FIG. **6** and described in detail below is performed by the controller **258**.

Turning now to method **600** illustrated in FIG. **6**. When operating, the wireless communication device is in communication with a network (not pictured) that provides channel assignments or allocations to the wireless communication device. The channel allocations are provided, for instance, when the device powers up, when the device becomes serviced by a different base station, when the device encounters poor signal quality, etc. For example, the network can provide channel allocations to the baseband processor for communicating control data and can provide channel allocations to one or more applications for communicating application or payload data.

In one example implementation, the wireless communication device, at **602**, receives an indication of: a first carrier frequency allocated from a first frequency band of a first set, e.g. plurality, of frequency bands, e.g., the LB; a second carrier frequency allocated from a second frequency band of a second set, e.g. plurality, of frequency bands, e.g., the HB; a third carrier frequency allocated from a third frequency band of the first plurality of frequency bands; and a fourth carrier frequency allocated from a fourth frequency band of the second plurality of frequency bands. The first, second, third, and fourth frequency bands can all be different or can include some common frequency bands. For example, the HB transmit and receive paths can have the same operating frequency band and/or the LB transmit and receive paths can have the same operating frequency band. However, the carrier frequencies are generally all different. The controller, at **604**, responsively, adjusts first and second antenna match networks **242**, **244**, at a minimum, based on the corresponding frequency bands of operation. If the antenna has a very narrow bandwidth, the controller can adjust the antenna match networks based on the specific active carrier frequencies.

Moreover, the frequencies at which blockers (e.g., intermodulation, half duplex, and image frequency) in the receive path or interfering signals in the transmit path appear can change depending on the frequency band of operation for a particular signal path. Therefore, the controller may need to tune one or more sets of notch filters upon receiving the indication of the active carrier frequencies.

Accordingly, at **606**, the controller tunes at least one filter within a first set of filters in a first signal path based on the first frequency band. At **608**, the controller tunes at least one filter within a second set of filters in a second signal path based on the second frequency band. The first and second signal paths are coupled to a first antenna, and whether the first and second signal paths are transmit or receive paths depends on the particular wireless communication device architecture (examples of which are shown in FIGS. **2-5**). At **610**, the controller tunes at least one filter within a third set of filters in a third signal path based on the third frequency band, and at **612** the controller tunes at least one filter within a fourth set of filters in a fourth signal path based on the fourth frequency band. The third and fourth signal paths are coupled to a second antenna, and whether the first and second signal paths are transmit or receive paths depends on the particular wireless communication device architecture (examples of which are shown in FIGS. **2-5**). In an embodiment, the filters that are tuned within the first, second, third, and fourth sets of filters are notch filters. Where the notch filters have sufficient sensitivity, in a further embodiment: the at least one filter within first set of filters is further tuned based on the first carrier frequency; the at least one filter within second set of filters is further tuned based on the second carrier frequency; the at least one filter within third set of filters is further tuned based on the third carrier frequency; and the at least one filter within fourth set of filters is further tuned based on the fourth carrier frequency.

When the wireless communication device is configured as depicted in FIG. **2**, the device **200** further performs the functionality of: receiving, at the first antenna **202**, a first signal transmitted over the first carrier frequency and filtering the first signal using the first set of filters **210**, **220**, **222**, **224**; and receiving, at the first antenna **202**, a second signal transmitted over the second carrier frequency and filtering the second signal using the second set of filters **212**, **226**, **228**, **230**. The device **200** further performs: filtering a third signal using the third set of filters **232** and transmitting the third signal over the third carrier frequency using the second antenna **204**; and filtering a fourth signal using the fourth set of filters **234** and transmitting the fourth signal over the fourth carrier frequency using the second antenna **204**.

When the wireless communication device is configured as depicted in FIG. **3**, the device **300** further performs the functionality of: receiving, at the first antenna **202**, a first signal transmitted over the first carrier frequency and filtering the first signal using the first set of filters **210**, **220**, **222**, **224**; and filtering a second signal using the second set of filters **234** and transmitting the second signal over the second carrier frequency using the first antenna **202**. The device **300** further performs: receiving, at the second antenna **204**, a third signal transmitted over the third carrier frequency and filtering the third signal using the third set of filters **212**, **226**, **228**, **230**; and filtering a fourth signal using the fourth set of filters **232** and transmitting the fourth signal over the fourth carrier frequency using the second antenna **204**.

Tuning back to method **600**, where at **614**, the device architecture only includes the two antennas and four signal paths, the method returns to **602** until different channel allocations are made. If, however, the device architecture included a third antenna (as in FIG. **4** or FIG. **5**), the controller, at **616** adjusts a third antenna match network **442** coupled to the third antenna **402**. The controller further, at **618** and **620**, tunes at least one filter within a fifth set of filters **408**, **410**, **412**, **414** in a fifth signal path **488** coupled to the third antenna **402** and tunes at least one filter within a sixth set of filters **416**, **418**, **420**, **422** in a sixth signal path **490** coupled to the third antenna **402**. In an embodiment, the filters that are tuned within the fifth and sixth sets of filters are notch filters. The tuning is based on a different one of the first, second, third or fourth frequency bands and more particularly based on a different one of the first, second, third or fourth carrier frequencies, depending on the particular wireless communication device configuration, e.g., as shown in FIG. **4** or FIG. **5**. The method then returns to **602** until different channel allocations are made.

In the foregoing specification, specific embodiments have been described. However, one of ordinary skill in the art appreciates that various modifications and changes can be made without departing from the scope of the invention as set forth in the claims below. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present teachings.

The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

Moreover in this document, relational terms such as first and second, top and bottom, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions. The terms "comprises," "comprising," "has", "having," "includes", "including," "contains", "containing" or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises, has, includes, contains a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by "comprises . . . a", "has . . . a", "includes . . . a", "contains . . . a" does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises, has, includes, contains the element. The terms "a" and "an" are defined as one or more unless explicitly stated otherwise herein. The terms "substantially", "essentially", "approximately", "about" or any other version thereof, are defined as being close to as understood by one of ordinary skill in the art, and in one non-limiting embodiment the term is defined to be within 10%, in another embodiment within 5%, in another embodiment within 1% and in another embodiment within 0.5%. The term "coupled" as used herein is defined as connected, although not necessarily directly and not necessarily mechanically. A device or structure that is "configured" in a certain way is configured in at least that way, but may also be configured in ways that are not listed.

It will be appreciated that some embodiments may be comprised of one or more generic or specialized processors (or "processing devices") such as microprocessors, digital signal processors, customized processors and field programmable gate arrays (FPGAs) and unique stored program instructions (including both software and firmware) that control the one or more processors to implement, in conjunction with certain non-processor circuits, some, most, or all of the functions of the method and/or apparatus described herein. Alternatively, some or all functions could be implemented by a state machine that has no stored program instructions, or in one or more application specific integrated circuits (ASICs), in which each function or some combinations of certain of the functions are implemented as custom logic. Of course, a combination of the two approaches could be used. Both the state machine and ASIC are considered herein as a "processing device" for purposes of the foregoing discussion and claim language.

Moreover, an embodiment can be implemented as a computer-readable storage medium having computer readable code stored thereon for programming a computer (e.g., comprising a processor) to perform a method as described and claimed herein. Examples of such computer-readable storage mediums include, but are not limited to, a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a ROM (Read Only Memory), a PROM (Programmable Read Only Memory), an EPROM (Erasable Programmable Read Only Memory), an EEPROM (Electrically Erasable Programmable Read Only Memory) and a Flash memory. Further, it is expected that one of ordinary skill, notwithstanding possibly significant effort and many design choices motivated by, for example, available time, current technology, and economic considerations, when guided by the concepts and principles disclosed herein will be readily capable of generating such software instructions and programs and ICs with minimal experimentation.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

We claim:

1. A wireless communication device adapted for multiband operation, the wireless communication device comprising:

a first antenna configured to communicate signals within a first set of high frequency bands and a second set of low frequency bands;

a first diplexer coupled to the first antenna and configured to pass signals within the first set of high frequency bands and the second set of low frequency bands;

first and second signal paths coupled to the first diplexer and comprising first and second receive paths, respectively, each signal path including a respective set of two or more notch filters, individual ones of the two or more notch filters in the respective set being tunable to attenuate a different frequency, and each signal path configured to communicate signals within a different one of the first set of high frequency bands and the second set of low frequency bands, the first receive path configured to communicate signals within the first set of high frequency bands, the first receive path including at least first, second, and third notch filters each tunable to attenuate a first transmit frequency, a first half duplex blocker frequency, or a first image blocker frequency, respectively, the second receive path configured to communicate signals within the second set of low frequency bands, the second receive path including at least fourth, fifth, and sixth notch filters each tunable to attenuate a second transmit frequency, a second half duplex blocker frequency, or a second image blocker frequency, respectively;

a second antenna configured to communicate signals within the first set of high frequency bands and the second set of low frequency bands;

a second diplexer coupled to the second antenna and configured to pass signals within the first set of high frequency bands and the second set of low frequency bands;

third and fourth signal paths coupled to the second diplexer and comprising first and second transmit paths, respectively, each of the third and fourth signal paths including an additional respective set of two or more notch filters, individual ones of the two or more notch filters in the additional respective set being tunable to attenuate a different frequency, and each of the third and fourth signal paths configured to communicate signals within a different one of the first set of high frequency bands and second set of low frequency bands; and

a transceiver, coupled to each signal path, configured to simultaneously communicate signals over the first antenna and the second antenna.

2. The wireless communication device of claim **1**, further comprising a first wideband filter configured to filter frequencies outside of the first set of high frequency bands and a second wideband filter configured to filter frequencies outside of the second set of low frequency bands, wherein each wideband filter is coupled to the first diplexer.

3. The wireless communication device of claim **2** further comprising:

a third antenna configured to communicate signals within the first set of high frequency bands and the second set of low frequency bands;

a third diplexer coupled to the third antenna and configured to pass signals, within the first set of high frequency bands and the second set of low frequency bands;

fifth and sixth signal paths coupled to the third diplexer and to the transceiver, wherein each of the fifth and sixth signal paths includes another set of two or more notch filters, and each of the fifth and sixth signal paths is configured to communicate signals within a different one of the first set of high frequency bands and the second set of low frequency bands;

a third wideband filter coupled to the third diplexer and included within the fifth signal path, wherein the third wideband filter is configured to filter frequencies outside of the first set of high frequency bands; and

a fourth wideband filter coupled to the third diplexer and included within the sixth signal path, wherein the fourth wideband filter is configured to filter frequencies outside of the second set of low frequency bands.

4. The wireless communication device of claim **3**, wherein:

the fifth signal path comprises a third receive path that includes a seventh notch filter, an eighth notch filter, and a ninth notch filter each tunable to attenuate a different frequency; and

the sixth signal path comprises a fourth receive path that includes a tenth notch filter, an eleventh notch filter and a twelfth notch filter each tunable to attenuate a different frequency.

5. The wireless communication device of claim **3**, wherein:

the third antenna and the first antenna are tuned to receive duplicate signals from a same channel of a same frequency band, the duplicate signals representing multiple copies of a transmitted signal; and

the transceiver is configured to communicate the duplicate signals to a baseband processor to correct transmission errors and recreate an original form of the transmitted signal.

6. The wireless communication device of claim **3**, wherein the first antenna and the third antenna are tuned to receive transmitted signals from same channels of same frequency bands effective to provide duplicate received signals, the transceiver configured to communicate the duplicate received signals to a baseband processor configured to recreate the received transmitted signals according to an original form of the received transmitted signals.

7. The wireless communication device of claim **1**, wherein:

the first transmit path includes a first transmit notch filter of the additional respective set in the third signal path, the first transmit notch filter being tunable to attenuate transmit frequencies in the first set of high frequency bands; and

the second transmit path includes a second transmit notch filter of the additional respective set in the fourth signal path, the second transmit notch filter being tunable to attenuate transmit frequencies in the second set of low frequency bands.

8. The wireless communication device of claim **1** further comprising a controller coupled to the two or more notch filters in each of the first, second, third, and fourth signal paths, wherein the controller is configured to tune the two or more notch filters in each of the first, second, third, and fourth signal paths depending on a set of frequency bands of operation within at least one of the first set of high frequency bands or the second set of low frequency bands.

9. The wireless communication device of claim **8**, wherein the controller is configured to tune the two or more notch filters in each of the first, second, third, and fourth signal paths depending on a set of allocated carrier frequencies of operation within at least one of the first set of high frequency bands or the second set of low frequency bands.

10. The wireless communication device of claim **1**, further comprising a controller coupled to the two or more notch filters in each of the first, second, third, and fourth signal paths, the controller configured to:

adjust a first antenna match network associated with the first antenna based on a first frequency of operation within the first set of high frequency bands to match a first impedance at the first antenna with a second impedance at the transceiver; and

adjust a second antenna match network associated with the second antenna based on a second frequency of operation within the second set of low frequency bands to match a third impedance at the second antenna with a fourth impedance at the transceiver.

11. A method, performed by a controller, for tuning a wireless communication device for multi-band operation, the method comprising:

receiving an indication of a first carrier frequency allocated from a first frequency band of a first plurality of high frequency bands, and tuning at least one filter within a first set of filters in a first signal path based on the first frequency band, the first signal path being coupled to a first antenna that is configured to communicate signals within high frequency bands and low frequency bands;

receiving via the first antenna a first signal transmitted over the first carrier frequency, and filtering the first signal using the first set of filters, the first set of filters including at least first, second, and third notch filters each tunable to attenuate a first transmit frequency, a first half duplex blocker frequency, or a first image blocker frequency, respectively;

receiving an indication of a second carrier frequency allocated from a second frequency band of a second plurality of low frequency bands, and tuning at least one filter within a second set of filters in a second signal path based on the second frequency band, the second signal paths being coupled to the first antenna;

receiving via the first antenna a second signal transmitted over the second carrier frequency, and filtering the second signal using the second set of filters, the second set of filters including at least fourth, fifth, and sixth notch filters each tunable to attenuate a second transmit frequency, a second half duplex blocker frequency, or a second image blocker frequency, respectively;

receiving an indication of a third carrier frequency allocated from a third frequency band of the first plurality of high frequency bands, and tuning at least one filter within a third set of filters in a third signal path based on the third frequency band;

receiving an indication of a fourth carrier frequency allocated from a fourth frequency band of the second plurality of low frequency bands, and tuning at least one filter within a fourth set of filters in a fourth signal path based on the fourth frequency band, the third and fourth signal paths being coupled to a second antenna; and

simultaneously communicating signals over the first antenna and the second antenna.

12. The method of claim **11**, wherein:

the at least one filter within the first set of filters is further tuned based on the first carrier frequency;

the at least one filter within the second set of filters is further tuned based on the second carrier frequency;

the at least one filter within the third set of filters is further tuned based on the third carrier frequency;

the at least one filter within the fourth set of filters is further tuned based on the fourth carrier frequency.

13. The method of claim **11** further comprising;

filtering a third signal using the third set of filters, and transmitting the third signal over the third carrier frequency using the second antenna; and

filtering a fourth signal using the fourth set of filters, and transmitting the fourth signal over the fourth carrier frequency using the second antenna.

14. The method of claim **11** further comprising tuning at least one filter within a fifth set of filters in a fifth signal path coupled to a third antenna and tuning at least one filter within a sixth set of filters in a sixth signal path coupled to the third antenna, wherein the tuning is based on a different one of the first, second, third, or fourth carrier frequencies.

15. The method of claim **11**, wherein the first signal path is coupled to a low band receive port of a transceiver and the second signal path is coupled to a high band receive port of the transceiver.

16. A wireless communication device adapted for multiband operation, the wireless communication device comprising:

a first antenna configured to communicate signals within a first set of high frequency bands and a second set of low frequency bands;

a first diplexer coupled to the first antenna and configured to pass signals within the first set of high frequency bands and the second set of low frequency bands;

first and second signal paths coupled to the first diplexer, the first signal path including a first receive path, the second signal path including a first transmit path, each signal path including a respective set of two or more notch filters, individual ones of the two or more notch filters in the respective set being tunable to attenuate a different frequency, and each signal path configured to communicate signals within a different one of the first set of high frequency bands and the second set of low frequency bands, the first receive path configured to communicate signals within the first set of high frequency bands, the first receive path including a first notch filter, a second notch filter, and a third notch filter each tunable to attenuate a different frequency;

a first wideband filter coupled to the first diplexer and included within the first receive path, the first wideband filter configured to filter frequencies outside the first set of high frequency bands;

a second antenna configured to communicate signals within the first set of high frequency bands and the second set of low frequency bands;

a second diplexer coupled to the second antenna and configured to pass signals within the first set of high frequency bands and the second set of low frequency bands;

third and fourth signal paths coupled to the second diplexer, the third signal path including a second receive path, the fourth signal path including a second transmit path, each of the third and fourth signal paths including an additional respective set of two or more notch filters, individual ones of the two or more notch filters in the additional respective set being tunable to attenuate a different frequency, and each of the third and fourth signal paths configured to communicate signals within a different one of the first set of high frequency bands and second set of low frequency bands, the second receive path configured to communicate signals within the second set of low frequency bands, the second receive path including a fourth notch filter, a fifth notch filter, and a sixth notch filter each tunable to attenuate a different frequency;

a second wideband filter coupled to the second diplexer and included within the second receive path, the second wideband filter configured to filter frequencies outside the second set of low frequency bands; and

a transceiver, coupled to each signal path, configured to simultaneously communicate signals over the first antenna and the second antenna.

17. The wireless communication device of claim **16**, wherein:

the first notch filter is tunable to attenuate a first transmit frequency;

the second notch filter is tunable to attenuate a first half duplex blocker frequency;

the third notch filter tunable to attenuate a first image blocker frequency;

the fourth notch filter is tunable to attenuate a second transmit frequency;

the fifth notch filter is tunable to attenuate a second half duplex blocker frequency; and

the sixth notch filter is tunable to attenuate a second image blocker frequency.

18. The wireless communication device of claim **16**, wherein:

the first transmit path includes a first transmit notch filter tunable to attenuate transmit frequencies in the second set of low frequency bands; and the second transmit path includes a second transmit notch filter tunable to attenuate transmit frequencies in the first set of high frequency bands.

19. The wireless communication device of claim **16**, further comprising:

a third antenna configured to communicate signals within the first set of high frequency bands and the second set of low frequency bands;

a third diplexer coupled to the third antenna and configured to pass signals within the first set of high frequency bands and the second set of low frequency bands;

fifth and sixth signal paths coupled to the third diplexer and to the transceiver, wherein each of the fifth and sixth signal paths includes another set of two or more notch filters, and each of the fifth and sixth signal paths is configured to communicate signals within a different one of the first set of high frequency bands and the second set of low frequency bands;

a third wideband filter coupled to the third diplexer and included within the fifth signal path, wherein the third wideband filter is configured to filter frequencies outside of the first set of high frequency bands; and

a fourth wideband filter coupled to the third diplexer and included within the sixth signal path, wherein the fourth wideband filter is configured to filter frequencies outside of the second set of low frequency bands.

20. The wireless communication device of claim **16**, wherein:

the fifth signal path comprises a third receive path that includes a seventh notch filter, an eighth notch, filter and a ninth notch filter each tunable to attenuate a different frequency; and

the sixth signal path comprises a fourth receive path that includes a tenth notch filter, an eleventh notch filter, and a twelfth notch filter each tunable to attenuate a different frequency.

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