APPARATUS AND METHODS FOR MULTI-BAND RADIO FREQUENCY SIGNAL ROUTING

BACKGROUND

Field

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

Description of the Related Technology

[0002] An RF system can include antennas for receiving and/or transmitting RF signals. However, there can be several components in an RF system that may need to access to the antennas. For example, an RF system can include different transmit or receive paths associated with different frequency bands, different communication standards, and/or different power modes, and each path may need access to a particular antenna at certain instances of time.

[0003] An antenna switch module can be used to electrically connect a particular antenna to a particular transmit or receive path of the RF system, thereby allowing multiple components to share antennas. In certain configurations, an antenna switch module is in communication with a diversity module, which processes signals that are received and/or transmitted using one or more diversity antennas.

SUMMARY

[0004] An aspect relates to a mobile device comprising at least one diversity antenna; a diversity module electrically coupled to the at least one diversity antenna, the diversity module configured to generate a high band signal, a mid band signal, and a low band signal based on processing one or more diversity signals received from the at least one diversity antenna, the high band signal having a frequency content that is greater than a frequency content of the mid band signal and the mid band signal having a frequency content that is greater than a frequency content of the low band signal, the diversity module further configured to generate a combined low band/high band signal based on combining the low band signal and the high band signal; and an antenna switch module configured to receive the mid band signal and the combined low band/high band signal from the diversity module. In an embodiment, the mobile device includes at least one diversity antenna, a diversity module electrically coupled to the at least one diversity antenna,

and an antenna switch module. The diversity module is electrically coupled to the at least one diversity antenna, and is configured to generate a high band (HB) signal, a mid band (MB) signal, and a low band (LB) signal based on processing one or more diversity signals received from the at least one diversity antenna. The HB signal has a frequency content that is greater than a frequency content of the MB signal and the MB signal has a frequency content that is greater than a frequency content of the LB signal. The diversity module is further configured to generate a combined LB/HB

signal based on combining the LB signal and the HB signal. The antenna switch module is configured to receive the MB signal and the combined LB/HB signal from the diversity module.

[0005] In a number of embodiments, the frequency content of the LB signal is less than 1 GHz, the frequency content of the MB signal is between 1 GHz and 2.3 GHz, and the frequency content of the HB signal is greater than 2.3 GHz.

[0006] In various embodiments, the mobile device further includes a transceiver and one or more primary antennas, and the transceiver is electrically coupled to the one or more primary antennas via the antenna switch module.

[0007] In some embodiments, the diversity module includes a diplexer configured to generate the combined LB/HB signal based on the LB signal and the HB signal.

[0008] Accordingly to certain embodiments, the diversity module includes a LB processing circuit configured to generate the LB signal, a MB processing circuit configured to generate the MB signal, and a HB processing circuit configured to generate the HB signal.

[0009] In some embodiments, the LB processing circuit includes a first filter and a first LNA arranged in a cascade, the MB processing circuit includes a second filter and a second LNA arranged in a cascade, and the HB processing circuit includes a third filter and a third LNA arranged in a cascade.

[0010] In various embodiments, the mobile device further includes a diversity antenna terminal configured to receive a combined MB/HB diversity signal, and a band selection switch including an input electrically coupled to the diversity antenna terminal, a first output electrically coupled to an input of the MB processing circuit, and a second output electrically coupled to an input of the HB processing circuit.

[0011] An aspect relates to a radio frequency system comprising a diversity module configured to generate a high band signal, a mid band signal, and a low band signal based on processing one or more diversity signals received from one or more diversity antenna terminals, the high band signal having a frequency content that is greater than a frequency content of the mid band signal and the mid band signal having a frequency content that is greater than a frequency content of the low band signal, the diversity module further configured to generate a combined low band/high band signal based on combining the low band signal and the high band signal; and

an antenna switch module configured to receive the mid band signal and the combined low band/high band signal from the diversity module. In an embodiment, there is method of front end

signal processing in a mobile device. The method includes receiving one or more diversity signals from at least one diversity antenna and generating a HB signal, a MB signal, and a LB signal based on processing the one or more diversity signals using a diversity module. The HB signal has a frequency content that is greater than a frequency content of the MB signal, and the MB signal has a frequency content that is greater than a frequency content of the LB signal. The method further includes generating a combined LB/HB signal based on combining the LB signal and the HB signal using the diversity module, providing

the MB signal to an antenna switch module over a first signal route, and providing the combined LB/HB signal to the antenna switch module over a second signal route.

[0012] According to a number of embodiments, the frequency content of the LB signal is less than 1 GHz, the frequency content of the MB signal is between 1 GHz and 2.3 GHz, and the frequency content of the HB signal is greater than 2.3 GHz.

[0013] In various embodiments, the method further includes receiving one or more primary signals from at least one primary antenna, and providing the one or more primary signals to the antenna switch module.

[0014] In some embodiments generating the combined LB/HB signal includes combining the LB signal and the HB signal using a diplexer.

[0015] An embodiment relates to a diversity module for a mobile device. The diversity module includes a LB processing circuit configured to generate a LB signal based on processing one or more diversity signals, a MB processing circuit configured to generate a MB signal based on processing the one or more diversity signals, and a HB processing circuit configured to generate a HB signal based on processing the one or more diversity signals. The MB signal has a frequency content that is greater than a frequency content of the LB signal, and the HB signal has a frequency content that is greater than a frequency content of the MB signal. The diversity module further includes a MB terminal configured to receive the MB signal, a shared LB/HB terminal, and a multi-throw switch electrically coupled to the shared LB/HB terminal. The multi-throw switch is configured to provide the LB signal to the shared LB/HB terminal in a first state and to provide the HB signal to the shared LB/HB terminal in a second state.

[0016] According to various embodiments, the frequency content of the LB signal is less than 1 GHz, the frequency content of the MB signal is between 1 GHz and 2.3 GHz, and the frequency content of the HB signal is greater than 2.3 GHz.

[0017] In some embodiments, the diversity module further includes a diplexer configured to combine the LB signal and the HB signal to generate a combined LB/HB signal, and the multi-throw switch is configured to provide the combined LB/HB signal to the shared LB/HB terminal in a third state. In certain embodiments, the diversity module further includes a first switch electrically coupled between an output of the HB processing circuit and a first input of the diplexer, and a second switch electrically coupled between an

output of the LB processing circuit and a second input of the diplexer. In various embodiments, the first and second switches are configured to close when the multi-throw switch operates in the third state and to open when the multi-throw switch operates in the first or second states.

[0018] In a number of embodiments, the LB processing circuit includes a first filter and a first LNA arranged in a cascade, the MB processing circuit includes a second filter and a second LNA arranged in a cascade, and the HB processing circuit includes a third filter and a third LNA arranged in a cascade.

[0019] In various embodiments, the diversity module further includes a first diversity antenna terminal configured to receive a LB diversity signal, and the first diversity antenna terminal is electrically coupled to an input of the LB processing circuit. In some embodiments, the diversity module further includes a second diversity antenna terminal configured to receive a combined MB/HB diversity signal, and a band selection switch including an input electrically coupled to the second diversity antenna terminal, a first output electrically coupled to an input of the MB processing circuit, and a second output electrically coupled to an input of the HB processing circuit.

[0020] According to some embodiments, the LB processing circuit includes a plurality of low band filters having different frequency ranges, the MB processing circuit includes a plurality of mid band filters having different frequency ranges, and the HB processing circuit includes a plurality of high band filters having different frequency ranges.

[0021] An embodiment relates to a diversity module. The diversity module includes a first antenna-side multi-throw switch, a second antenna-side multi-throw switch, a first transceiver-side multi-throw switch, a second transceiver-side multi-throw switch, a LB processing circuit configured to generate a LB signal, a MB processing circuit configured to generate a MB signal having a frequency content that is greater than a frequency content of the LB signal, and a HB processing circuit configured to generate a HB signal having a frequency content that is greater than the frequency content of the MB signal. The LB processing circuit is electrically coupled in a first signal path between the first antenna-side multi-throw switch and the first transceiver-side multi-throw switch, the MB processing circuit electrically coupled in a second signal path between the second antenna-side multi-throw switch and the second transceiver-side

multi-throw switch, and the HB processing circuit is electrically coupled in a third signal path between the second antenna-side multi-throw switch and the first transceiver-side multi-throw switch.

[0022] In a number of embodiments, the frequency content of the LB signal is less than 1 GHz, the frequency content of the MB signal is between 1 GHz and 2.3 GHz, and the frequency content of the HB signal is greater than 2.3 GHz.

[0023] In various embodiments, the diversity module further includes a first transmit bypass path between the first transceiver-side multi-throw switch and the first antenna-side multi-throw switch, and a second transmit bypass path between the second transceiver-side multi-throw switch and the second antenna-side multi-throw switch.

[0024] According to certain embodiments, the diversity module is operable in a plurality of modes including a normal operating mode and a swap mode. Additionally, the first transceiver-side multi-throw switch and the first antenna-side multi-throw switch are configured to select the first transmit bypass path in the swap mode, and the second transceiver-side multi-throw switch and the second antenna-side multi-throw switch are configured to select the second transmit bypass path in the swap mode.

[0025] In some embodiments, the diversity module further includes a first diversity antenna terminal electrically coupled to the first antenna-side multi-throw switch, a second diversity antenna terminal electrically coupled to the second antenna-side multi-throw switch, a first bidirectional terminal electrically coupled to the first transceiver-side multi-throw switch, and a second bidirectional terminal electrically coupled to the second transceiver-side multi-throw switch.

[0026] In various embodiments, the diversity module is operable in a plurality of modes including a normal operating mode and a swap mode, and the first transceiver-side multi-throw switch is configured to provide one of the LB signal or the HB signal to the first bidirectional terminal in the normal operating mode, and the second transceiver-side multi-throw switch is configured to provide MB signal to the second bidirectional terminal in the normal operating mode.

[0027] In some embodiments, the first transceiver-side multi-throw switch and the first antenna-side multi-throw switch are configured to electrically couple the first bidirectional terminal to the first diversity antenna terminal via the first transmit bypass path

in the swap mode, and the second transceiver-side multi-throw switch and the second antenna-side multi-throw switch are configured to electrically couple the second bidirectional terminal to the second diversity antenna terminal via the second transmit bypass path in the swap mode.

[0028] According to a number of embodiments, the LB processing circuit includes a first filter and a first LNA arranged in a cascade, the MB processing circuit includes a second filter and a second LNA arranged in a cascade, and the HB processing circuit includes a third filter and a third LNA arranged in a cascade.

[0029] An embodiment relates to a mobile device. The mobile device includes a transceiver, an antenna switch module, at least one diversity antenna, and a diversity module that includes a transceiver-side and an antenna-side. The diversity module is electrically coupled to the transceiver via the antenna switch module on the transceiver-side and is electrically coupled to the at least one diversity antenna on the antenna-side. The diversity module includes a first antenna-side multi-throw switch, a second antenna-side multi-throw switch, a first transceiver-side multi-throw switch, a second transceiver-side multi-throw switch, a LB processing circuit, a MB processing circuit, and a HB processing circuit. The LB processing circuit is electrically coupled in a first signal path between the first antenna-side multi-throw switch and the first transceiver-side multi-throw switch, the MB processing circuit is electrically coupled in a second signal path between the second antenna-side multi-throw switch and the second transceiver-side multi-throw switch, and the HB processing circuit is electrically coupled in a third signal path between the second antenna-side multi-throw switch and the first transceiver-side multi-throw switch.

[0030] In various embodiments, the LB processing circuit is configured to generate a LB signal based on processing one or more diversity signals received from the at least one diversity antenna, the MB processing circuit is configured to generate a MB signal having a frequency content that is greater than a frequency content of the LB signal based on processing the one or more diversity signals, and the HB processing circuit is configured to generate a HB signal having a frequency content that is greater than the frequency content of the MB signal based on processing the one or more diversity signals.

[0031] In certain embodiments, the frequency content of the LB signal is less than 1 GHz, the frequency content of the MB signal is between 1 GHz and 2.3 GHz, and the frequency content of the HB signal is greater than 2.3 GHz.

[0032] According to some embodiments, the diversity module further includes a first transmit bypass path between the first transceiver-side multi-throw switch and the first antenna-side multi-throw switch, and a second transmit bypass path between the second transceiver-side multi-throw switch and the second antenna-side multi-throw switch.

[0033] In various embodiments, the diversity module is operable in a plurality of modes including a normal operating mode and a swap mode, the first transceiver-side multi-throw switch and the first antenna-side multi-throw switch configured to select the first transmit bypass path in the swap mode, and the second transceiver-side multi-throw switch and the second antenna-side multi-throw switch configured to select the second transmit bypass path in the swap mode.

[0034] In certain embodiments, the first transceiver-side multi-throw switch is configured to select an output of the HB processing circuit or an output of the LB processing circuit in the normal operating mode, and the second transceiver-side multi-throw switch is configured to select an output of the MB processing circuit in the normal operating mode.

[0035] In various embodiments, the LB processing circuit includes a first filter and a first LNA arranged in a cascade, the MB processing circuit includes a second filter and a second LNA arranged in a cascade, and the HB processing circuit includes a third filter and a third LNA arranged in a cascade.

[0036] According to certain embodiments, the mobile device further includes one or more primary antennas, and the transceiver is electrically coupled to the one or more primary antennas via the antenna switch module.

[0037] An embodiment relates to a method of signal processing in a diversity module. The method includes receiving one or more diversity signals using at least one diversity antenna, and generating a LB signal based on processing the one or more diversity signals using a LB processing circuit that is electrically coupled in a first signal path between a first antenna-side multi-throw switch and a first transceiver-side multi-throw switch. The method further includes generating a MB signal based on processing the one or more diversity signals using a MB processing circuit that is

What is claimed is:

1. A mobile device comprising:

at least one diversity antenna;

a diversity module electrically coupled to the at least one diversity antenna, the diversity module configured to generate a high band signal, a mid band signal, and a low band signal based on processing one or more diversity signals received from the at least one diversity antenna, the high band signal having a frequency content that is greater than a frequency content of the mid band signal and the mid band signal having a frequency content that is greater than a frequency content of the low band signal, the diversity module further configured to generate a combined low band/high band signal based on combining the low band signal and the high band signal; and

an antenna switch module configured to receive the mid band signal and the combined low band/high band signal from the diversity module.

2. The mobile device of claim 1 wherein the frequency content of the low band signal is less than 1 GHz, the frequency content of the mid band signal is between 1 GHz and 2.3 GHz, and the frequency content of the high band signal is greater than 2.3 GHz.

3. The mobile device of claim 1 further comprising a transceiver and one or more primary antennas, the transceiver electrically coupled to the one or more primary antennas via the antenna switch module.

4. The mobile device of claim 1 wherein the diversity module includes a diplexer configured to generate the combined low band/high band signal based on the low band signal and the high band signal.

5. The mobile device of claim 1 wherein the diversity module includes a low band processing circuit configured to generate the low band signal, a mid band processing circuit configured to generate the mid band signal, and a high band processing circuit configured to generate the high band signal.

6. The mobile device of claim 5 wherein the low band processing circuit includes a first filter and a first low noise amplifier arranged in a cascade, the mid band processing circuit includes a second filter and a second low noise amplifier arranged in a cascade, and the high band processing circuit includes a third filter and a third low noise amplifier arranged in a cascade.

7. The mobile device of claim 5 further comprising a diversity antenna terminal configured to receive a combined mid band/high band diversity signal, and a band selection switch including an input electrically coupled to the diversity antenna terminal, a first output electrically coupled to an input of the mid band processing circuit, and a second output electrically coupled to an input of the high band processing circuit.

8. A method of front end signal processing in a mobile device, the method comprising:

receiving one or more diversity signals from at least one diversity antenna;

generating a high band signal, a mid band signal, and a low band signal based on processing the one or more diversity signals using a diversity module, the high band signal having a frequency content that is greater than a frequency content of the mid band signal and the mid band signal having a frequency content that is greater than a frequency content of the low band signal;

generating a combined low band/high band signal based on combining the low band signal and the high band signal using the diversity module;

providing the mid band signal to an antenna switch module over a first signal route; and

providing the combined low band/high band signal to the antenna switch module over a second signal route.

9. The method of claim 8 wherein the frequency content of the low band signal is less than 1 GHz, the frequency content of the mid band signal is between 1 GHz and 2.3 GHz, and the frequency content of the high band signal is greater than 2.3 GHz.

10. The method of claim 8 further comprising receiving one or more primary signals from at least one primary antenna, and providing the one or more primary signals to the antenna switch module.

11. The method of claim 8 wherein generating the combined low band/high band signal includes combining the low band signal and the high band signal using a diplexer.

12. A radio frequency system comprising:

a diversity module configured to generate a high band signal, a mid band signal, and a low band signal based on processing one or more diversity signals received from one or more diversity antenna terminals, the high band signal having a frequency content that is greater than a frequency content of the mid band signal and the mid band signal having a frequency

content that is greater than a frequency content of the low band signal, the diversity module further configured to generate a combined low band/high band signal based on combining the low band signal and the high band signal; and

an antenna switch module configured to receive the mid band signal and the combined low band/high band signal from the diversity module.

13. The radio frequency system of claim 12 wherein the frequency content of the low band signal is less than 1 GHz, the frequency content of the mid band signal is between 1 GHz and 2.3 GHz, and the frequency content of the high band signal is greater than 2.3 GHz.

14. The radio frequency system of claim 12 further comprising a transceiver and one or more primary antennas, the transceiver electrically coupled to the one or more primary antennas via the antenna switch module.

15. The radio frequency system of claim 12 wherein the diversity module includes a diplexer configured to generate the combined low band/high band signal based on the low band signal and high band signal.

16. The radio frequency system of claim 12 wherein the diversity module includes a low band processing circuit configured to generate the low band signal, a mid band processing circuit configured to generate the mid band signal, and a high band processing circuit configured to generate the high band signal.

17. The radio frequency system of claim 16 wherein the low band processing circuit includes a first filter and a first low noise amplifier arranged in a cascade, the mid band processing circuit includes a second filter and a second low noise amplifier arranged in a cascade, and the high band processing circuit includes a third filter and a third low noise amplifier arranged in a cascade.

18. The radio frequency system of claim 16 wherein the one or more diversity antenna terminals includes a first diversity antenna terminal electrically coupled to an input of the low band processing circuit.

19. The radio frequency system of claim 18 wherein the one or more diversity antenna terminals further includes a second diversity antenna terminal, the diversity module further including a band selection switch including an input electrically coupled to the second diversity antenna terminal, a first output electrically coupled to an input of the mid band

processing circuit, and a second output electrically coupled to an input of the high band processing circuit.