DISCRETE TIME CANCELLATION FOR PROVIDING COEXSITENCE IN RADIO FREQUENCY COMMUNICATION SYSTEMS

BACKGROUND

Field

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

Description of Related Technology

[0002] Radio frequency (RF) communication systems can be used for transmitting and/or receiving signals of a wide range of frequencies. For example, an RF communication system can be used to wirelessly communicate RF signals in a frequency range of about 30 kHz to 300 GHz, such as in the range of about 410 MHz to about 7.125 GHz for fifth generation (5G) frequency range 1 (FR1) communications.

[0003] Examples of RF communication systems include, but are not limited to, mobile phones, tablets, base stations, network access points, customer-premises equipment (CPE), laptops, and wearable electronics.

SUMMARY

[0004] In ~~certain embodiments~~an aspect, the present disclosure relates to a mobile device. The mobile device includes a first front end system configured to output a radio frequency receive signal and a first radio frequency observation signal, and a first transceiver including a receive channel configured to process the radio frequency receive signal to generate a first digital baseband receive signal, a first observation channel configured to process the first radio frequency observation signal to generate a first digital observation signal, a first spectral regrowth baseband sampling circuit configured to process the first digital observation signal to generate spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal, and a discrete time cancellation circuit configured to compensate the first digital baseband receive signal for radio frequency signal

leakage based on the spectral regrowth observation data and on direct transmit leakage observation data.

[0005] In some ~~embodiments~~examples, the mobile device further includes a second transceiver configured to provide the direct transmit leakage observation data to the first transceiver.

[0006] According to various ~~embodiments~~examples, the second transceiver includes a second observation channel configured to process a second radio frequency observation signal to generate a second digital observation signal, and a direct transmit leakage baseband sampling circuit configured to process the second digital observation signal to generate the direct transmit leakage observation data. In accordance with a number of the examples~~embodiments~~, the mobile device further includes a second front end system configured to output the second radio frequency observation signal and a radio frequency transmit signal. According to several examples~~embodiments~~, the first front end system includes a first directional coupler configured to generate the first radio frequency observation signal, and the second front end system includes a second directional coupler configured to generate the second radio frequency observation signal. In accordance with various examples~~embodiments~~, the mobile device further includes a first antenna coupled to the first front end system and a second antenna coupled to the second front end system, the first directional coupler configured to generate the first radio frequency observation signal based on a reverse coupled path to the first antenna, and the second directional coupler configured to generate the second radio frequency observation signal based on a forward coupled path to the second antenna. According to a number of examples~~embodiments~~, the direct transmit leakage observation data indicates an amount of direct transmit leakage present in the radio frequency transmit signal. In accordance with several examples~~embodiments~~, the first transceiver is a cellular transceiver and the second transceiver is a WiFi transceiver. According to a number of examples~~embodiments~~, the first transceiver is a WiFi transceiver and the second transceiver is a cellular transceiver. In accordance with various examples~~embodiments~~, the second transceiver includes a discrete time cancellation circuit configured to compensate a second digital baseband receive signal for radio frequency signal leakage.

[0007] In some ~~embodiments~~examples, the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal.

[0008] In a number of ~~embodiments~~examples, the first front end system includes a first directional coupler configured to generate the first radio frequency observation signal.

[0009] In several ~~embodiments~~examples, the mobile device further includes a first antenna coupled to the first front end system, and the first directional coupler is configured to generate the first radio frequency observation signal based on a reverse coupled path to the first antenna. According to various examples~~embodiments~~, the first front end system includes a duplexer, and the first directional coupler is positioned between an output of the duplexer

and the first antenna. In accordance with a number of examples~~embodiments~~, the first front end system includes a duplexer and a power amplifier, and the first directional coupler is positioned between an output of the power amplifier and an input to the duplexer.

[0010] In ~~certain embodiments~~another aspect, the present disclosure relates to a transceiver. The transceiver includes a receive channel configured to process a radio frequency receive signal to generate a digital baseband receive signal, a first observation channel configured to process a first radio frequency observation signal to generate a first digital observation signal, a spectral regrowth baseband sampling circuit configured to process the first digital observation signal to generate spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal, and a discrete time cancellation circuit configured to compensate the digital baseband receive signal for radio frequency signal leakage based on the spectral regrowth observation data and on direct transmit leakage observation data.

[0011] In a number of ~~embodiments~~examples, the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal.

[0012] In various ~~embodiments~~examples, the direct transmit leakage observation data indicates an amount of direct transmit leakage present in an aggressor radio frequency transmit signal.

[0013] In several examples~~embodiments~~, the transceiver is configured to receive the direct transmit leakage observation data from another transceiver.

[0014] In some examples~~embodiments~~, the transceiver is implemented as cellular transceiver.

[0015] In a number of examples~~embodiments~~, the transceiver is implemented as WiFi transceiver.

[0016] In various examples~~embodiments~~, the transceiver further includes a second observation channel configured to process a second radio frequency observation signal to generate a second digital observation signal, and a first direct transmit leakage baseband sampling circuit configured to process the second digital observation signal to generate first transmit leakage observation data.

[0017] According to a number of examples~~embodiments~~, the transceiver is configured to output the first transmit leakage observation data to another transceiver.

[0018] In accordance with several examples~~embodiments~~, the transceiver further includes a second direct transmit leakage baseband sampling circuit configured to process

a third digital observation signal to generate second transmit leakage observation data, and an observation switch configured to selectively provide the first transmit leakage observation data or the second transmit leakage observation data as an output of the transceiver. According to various examplesembodiments, the transceiver further includes a third observation channel configured to process a third radio frequency observation signal to generate the third digital observation signal. In accordance with a number of examplesembodiments, the transceiver further includes a transmit power control circuit configured to receive second digital observation signal.

[0019] In certain embodimentsanother aspect, the present disclosure relates to a method of coexistence management in a mobile device. The method includes processing a radio frequency receive signal to generate a digital baseband receive signal using a receive channel of a first transceiver, processing a first radio frequency observation signal to generate a first digital observation signal using a first observation channel of the first transceiver, generating spectral regrowth observation data based on processing process the first digital observation signal using a first spectral regrowth baseband sampling circuit of the first transceiver, the spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal, and compensating the digital baseband receive signal for radio frequency signal leakage based on the spectral regrowth observation data and on direct transmit leakage observation data using a discrete time cancellation circuit of the first transceiver.

[0020] In some examplesembodiments, the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal.

[0021] In various examplesembodiments, the direct transmit leakage observation data indicates an amount of direct transmit leakage present in an aggressor radio frequency transmit signal.

[0022] In several examplesembodiments, the method further includes receiving the direct transmit leakage observation data from a second transceiver. According to a number of examplesembodiments, the first transceiver is a cellular transceiver and the second transceiver is a WiFi transceiver. In accordance with various examplesembodiments, the first transceiver is a WiFi transceiver and the second transceiver is a cellular transceiver.

[0023] In some examplesembodiments, the method further includes processing a second radio frequency observation signal to generate a second digital observation signal using a second observation channel of the first transceiver, and processing the second digital observation signal to generate leakage observation data using a direct transmit leakage

baseband sampling circuit of the first transceiver. According to several examples~~embodiments~~, the method further includes providing the leakage observation data from the first transceiver to a second transceiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 is a schematic diagram of one example of a mobile device communicating via cellular and WiFi networks.

[0025] Figure 2 is a schematic diagram of one example of signal leakage for an RF communication system.

[0026] Figure 3A is a schematic diagram of one example of direct transmit leakage for an RF communication system.

[0027] Figure 3B is a schematic diagram of one example of regrowth leakage for an RF communication system.

[0028] Figure 4A is a schematic diagram of an RF communication system with coexistence management according to one embodiment.

[0029] Figure 4B is a schematic diagram of an RF communication system with coexistence management according to another embodiment.

[0030] Figure 5 is a schematic diagram of an RF communication system with coexistence management according to another embodiment.

[0031] Figure 6 is a schematic diagram of an RF communication system with coexistence management according to another embodiment.

[0032] Figure 7 is a schematic diagram of an RF communication system with coexistence management according to another embodiment.

[0033] Figure 8 is a schematic diagram of one embodiment of a mobile device with coexistence management.

[0034] Figure 9A is a schematic diagram of one embodiment of a packaged module with coexistence management.

[0035] Figure 9B is a schematic diagram of a cross-section of the packaged module of Figure 9A taken along the lines 9B–9B.

DETAILED DESCRIPTION OF EMBODIMENTS

[0036] The following detailed description of certain embodiments presents various descriptions of specific embodiments. However, the innovations described herein

WHAT IS CLAIMED IS:

1. A mobile device comprising:

a first front end system configured to output a radio frequency receive signal and a first radio frequency observation signal; and

a first transceiver including a receive channel configured to process the radio frequency receive signal to generate a first digital baseband receive signal, a first observation channel configured to process the first radio frequency observation signal to generate a first digital observation signal, a first spectral regrowth baseband sampling circuit configured to process the first digital observation signal to generate spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal, and a discrete time cancellation circuit configured to compensate the first digital baseband receive signal for radio frequency signal leakage based on the spectral regrowth observation data and on direct transmit leakage observation data.

2. The mobile device of claim 1 further comprising a second transceiver configured to provide the direct transmit leakage observation data to the first transceiver.

3. The mobile device of claim 2 wherein the second transceiver includes a second observation channel configured to process a second radio frequency observation signal to generate a second digital observation signal, and a direct transmit leakage baseband sampling circuit configured to process the second digital observation signal to generate the direct transmit leakage observation data.

4. The mobile device of claim 3 further comprising a second front end system configured to output the second radio frequency observation signal and a radio frequency transmit signal.

5. The mobile device of claim 4 wherein the first front end system includes a first directional coupler configured to generate the first radio frequency observation signal, and the second front end system includes a second directional coupler configured to generate the second radio frequency observation signal.

6. The mobile device of claim 5 further comprising a first antenna coupled to the first front end system and a second antenna coupled to the second front end system, the first directional coupler configured to generate the first radio frequency observation signal based on a reverse coupled path to the first antenna, and the second directional coupler configured to generate the second radio frequency observation signal based on a forward coupled path to the second antenna.

7. The mobile device of claim 4 wherein the direct transmit leakage observation data indicates an amount of direct transmit leakage present in the radio frequency transmit signal.

8. The mobile device of claim 2 wherein the second transceiver includes a discrete time cancellation circuit configured to compensate a second digital baseband receive signal for radio frequency signal leakage.

~~9. The mobile device of claim 1 wherein the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal.~~

~~10.~~9. The mobile device of claim 1 wherein the first front end system includes a first directional coupler configured to generate the first radio frequency observation signal.

~~11.~~10. The mobile device of claim 1 further comprising a first antenna coupled to the first front end system, the first directional coupler configured to generate the first radio frequency observation signal based on a reverse coupled path to the first antenna.

~~12.~~11. The mobile device of claim ~~11~~ 10 wherein the first front end system includes a duplexer, the first directional coupler positioned between an output of the duplexer and the first antenna.

~~13.~~12. The mobile device of claim ~~11~~ 10 wherein the first front end system includes a duplexer and a power amplifier, the first directional coupler positioned between an output of the power amplifier and an input to the duplexer.

~~14.~~13. A transceiver comprising:

a receive channel configured to process a radio frequency receive signal to generate a digital baseband receive signal;

a first observation channel configured to process a first radio frequency observation signal to generate a first digital observation signal;

a spectral regrowth baseband sampling circuit configured to process the first digital observation signal to generate spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal; and

a discrete time cancellation circuit configured to compensate the digital baseband receive signal for radio frequency signal leakage based on the spectral regrowth observation data and on direct transmit leakage observation data.

~~15. The transceiver of claim 14 wherein the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal.~~

~~16.~~14. The transceiver of claim ~~14~~ 13 wherein the direct transmit leakage observation data indicates an amount of direct transmit leakage present in an aggressor radio frequency transmit signal.

~~17.~~15. The transceiver of claim ~~14~~ 13 further comprising a second observation channel configured to process a second radio frequency observation signal to generate a second digital observation signal, and a first direct transmit leakage baseband sampling circuit configured to process the second digital observation signal to generate first transmit leakage observation data.

~~18.~~16. A method of coexistence management in a mobile device, the method comprising:

processing a radio frequency receive signal to generate a digital baseband receive signal using a receive channel of a first transceiver;

processing a first radio frequency observation signal to generate a first digital observation signal using a first observation channel of the first transceiver;

generating spectral regrowth observation data based on processing ~~process~~ the first digital observation signal using a first spectral regrowth baseband sampling circuit of the first transceiver, the spectral regrowth observation data indicating an amount of aggressor spectral regrowth present in the radio frequency receive signal; and

compensating the digital baseband receive signal for radio frequency signal leakage based on the spectral regrowth observation data and on direct transmit leakage observation data using a discrete time cancellation circuit of the first transceiver.

~~19.~~17. The method of claim ~~18~~ 16 wherein ~~the spectral regrowth observation data indicates an amount of aggressor spectral regrowth present in the radio frequency receive signal, and~~ the direct transmit leakage observation data indicates an amount of direct transmit leakage present in an aggressor radio frequency transmit signal.

~~20.~~18. The method of claim ~~18~~ 16 further comprising receiving the direct transmit leakage observation data from a second transceiver.