RADIO FREQUENCY COMMUNICATION SYSTEMS WITH DISCRETE TIME CANCELLATION FOR COEXISTENCE MANAGEMENT

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 antenna, a second antenna, a first front end system configured to process a radio frequency receive signal from the first antenna, and a first transceiver configured to further process the radio frequency receive signal to generate a first digital baseband receive signal. The first transceiver includes a discrete time cancellation circuit configured to compensate the first digital baseband receive signal for radio frequency signal leakage based on digital observation data, the discrete time cancellation circuit including a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data. The mobile device further includes a second front end system configured to process a radio frequency transmit signal for transmission on the second antenna, and to generate a radio frequency observation signal based on observing the radio frequency transmit signal, and a second transceiver configured to process the radio frequency observation signal to generate the digital observation data, and to provide the

digital observation data to the first transceiver.

[0004a] In another aspect, the present disclosure refers to a transceiver comprising: a receive channel configured to process a radio frequency receive signal to generate a digital baseband receive signal; an observation channel configured to process a radio frequency observation signal to generate a digital observation signal; a baseband sampling circuit configured to sample the digital observation signal to generate first digital observation data; an output configured to output the first digital observation data; an input configured to receive second digital observation data; and a discrete time cancellation circuit configured to compensate the digital baseband receive signal for radio frequency signal leakage based on the second digital observation data, the discrete time cancellation circuit including a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the second digital observation data.

[0004b] In another aspect, the present disclosure refers to a method of coexistence management in a mobile device, the method comprising: providing a radio frequency receive signal from a first front end system to a first transceiver; processing the radio frequency receive signal to generate a first digital baseband receive signal using the first transceiver; compensating the first digital baseband receive signal for radio frequency signal leakage based on digital observation data using a discrete time cancellation circuit of the first transceiver, including estimating an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data using a spectral regrowth modeling circuit; generating a radio frequency observation signal based on observing a radio frequency transmit signal using a second front end system; and processing the radio frequency observation signal to generate the digital observation data using a second transceiver.

[0005] In some ~~embodiments~~examples, the discrete time cancellation circuit includes a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data.

According to a number of examples~~embodiments~~, the spectral regrowth modeling circuit is configured to estimate the amount of aggressor spectral regrowth based on modeling adjacent channel leakage ratio using predistortion.

[0006] In several examples~~embodiments~~, the second transceiver is configured to generate a digital observation signal based on the radio frequency observation signal, and the second transceiver includes a baseband sampling circuit configured to sample the digital observation signal to generate the digital observation data. According to various examples~~embodiments~~, the baseband sampling circuit generates the digital observation data to reflect an amount of direct transmit leakage present in the radio frequency transmit signal.

[0007] In some examples~~embodiments~~, the second front end system includes a directional coupler configured to generate the radio frequency observation signal. According to a number of examples~~embodiments~~, the directional coupler generates the radio frequency observation signal based on a forward coupled path to the second antenna.

[0008] In several examples~~embodiments~~, the first front end system is a cellular front end system and the second front end system is a WiFi front end system.

[0009] In various examples~~embodiments~~, the first front end system is a WiFi front end system and the second front end system is a cellular front end system.

[0010] In a number of examples~~embodiments~~, the second transceiver is configured to compensate a second baseband receive signal for radio frequency signal leakage based on additional digital observation data from the first transceiver. According to several examples~~embodiments~~, the first transceiver is configured to receive a sensed radio frequency signal from a directional coupler of the first front end system, and to process the sensed radio frequency signal to generate the additional digital observation data provided to the second transceiver. In accordance with several examples~~embodiments~~, the first front end system includes a duplexer, the directional coupler positioned between an output of the duplexer and the first antenna. According to some examples~~embodiments~~, the first front end system includes a duplexer and a power amplifier, and the directional coupler is positioned between an output of the power amplifier and an input to the duplexer.

[0011] In certain examples~~embodiments~~, the present disclosure relates to a transceiver including a receive channel configured to process a radio frequency receive signal to generate a digital baseband receive signal, an observation channel configured to process a radio frequency observation signal to generate a digital observation signal, a baseband sampling circuit configured to sample the digital observation signal to generate first digital

observation data, an output configured to output the first digital observation data, an input configured to receive second digital observation data, and a discrete time cancellation circuit configured to compensate the digital baseband receive signal for radio frequency signal leakage based on the second digital observation data.

[0012] In various examples~~embodiments~~, the discrete time cancellation circuit includes a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the second digital observation data. According to a number of examples~~embodiments~~, the spectral regrowth modeling circuit is configured to estimate the amount of aggressor spectral regrowth based on modeling adjacent channel leakage ratio using predistortion.

[0013] In several examples~~embodiments~~, the second digital observation data indicates an amount of direct transmit leakage present in an aggressor radio frequency transmit signal.

[0014] According to a number of examples~~embodiments~~, the transceiver further includes a transmit chancel configured to generate a radio frequency transmit signal.

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

[0016] In several examples~~embodiments~~, the transceiver is implemented as a WiFi transceiver.

[0017] In certain examples~~embodiments~~, the present disclosure relates to a method of coexistence management in a mobile device, the method including providing a radio frequency receive signal from a first front end system to a first transceiver, processing the radio frequency receive signal to generate a first digital baseband receive signal using the first transceiver, compensating the first digital baseband receive signal for radio frequency signal leakage based on digital observation data using a discrete time cancellation circuit of the first transceiver, generating a radio frequency observation signal based on observing a radio frequency transmit signal using a second front end system, and processing the radio frequency observation signal to generate the digital observation data using a second transceiver.

[0018] In various examples~~embodiments~~, the method further includes providing the digital observation data from the second transceiver to the first transceiver.

[0019] In a number of examples~~embodiments~~, the method further includes compensating the first digital baseband receive signal includes estimating an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data

using a spectral regrowth modeling circuit. According to several examples~~embodiments~~, estimating the amount of aggressor spectral regrowth includes modeling adjacent channel leakage ratio using predistortion.

[0020] In various examples~~embodiments~~, processing the radio frequency observation signal to generate the digital observation data includes generating a digital observation signal based on the radio frequency observation signal, and sampling the digital observation signal to generate the baseband observation data. In according with a number of examples~~embodiments~~, the method further includes generating the digital observation data to reflect an amount of direct transmit leakage present in the radio frequency transmit signal.

[0021] In several examples~~embodiments~~, the method further includes generating the radio frequency observation signal using a directional coupler of the second front end system.

[0022] In some examples~~embodiments~~, the first front end system is a cellular front end system and the second front end system is a WiFi front end system.

[0023] In a number of examples~~embodiments~~, the first front end system is a WiFi front end system and the second front end system is a cellular front end system.

[0024] In various examples~~embodiments~~, the method further includes compensating a second baseband receive signal of the second transceiver for radio frequency signal leakage based on additional digital observation data from the first transceiver.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] Figure 1 is a schematic diagram of one example of a mobile device communicating via cellular and WiFi networks.

[0026] Figure 2 is a schematic diagram of one example of signal leakage for an RF communication system.

[0027] Figure 3A is a schematic diagram of one example of direct transmit leakage for an RF communication system.

[0028] Figure 3B is a schematic diagram of one example of regrowth leakage for an RF communication system.

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

[0030] Figure 4B is a schematic diagram of an RF communication system with coexistence management according to another embodiment.

WHAT IS CLAIMED IS:

1. A mobile device comprising:

a first antenna and a second antenna;

a first front end system configured to process a radio frequency receive signal from the first antenna;

a first transceiver configured to further process the radio frequency receive signal to generate a first digital baseband receive signal, the first transceiver including a discrete time cancellation circuit configured to compensate the first digital baseband receive signal for radio frequency signal leakage based on digital observation data, the discrete time cancellation circuit including a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data;

a second front end system configured to process a radio frequency transmit signal for transmission on the second antenna, and to generate a radio frequency observation signal based on observing the radio frequency transmit signal; and

a second transceiver configured to process the radio frequency observation signal to generate the digital observation data, and to provide the digital observation data to the first transceiver.

~~2. The mobile device of claim 1 wherein the discrete time cancellation circuit includes a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data.~~

~~3.~~2. The mobile device of claim ~~2~~ 1 wherein the spectral regrowth modeling circuit is configured to estimate the amount of aggressor spectral regrowth based on modeling adjacent channel leakage ratio using predistortion.

~~4.~~3. The mobile device of claim 1 wherein the second transceiver is configured to generate a digital observation signal based on the radio frequency observation signal, the second transceiver including a baseband sampling circuit configured to sample the digital observation signal to generate the digital observation data.

~~5.~~4. The mobile device of claim ~~4~~ 3 wherein the baseband sampling circuit generates the digital observation data to reflect an amount of direct transmit leakage present in the radio frequency transmit signal.

~~6.~~5. The mobile device of claim 1 wherein the second front end system includes a directional coupler configured to generate the radio frequency observation signal.

~~7.~~6. The mobile device of claim ~~6~~ 5 wherein the directional coupler generates the radio frequency observation signal based on a forward coupled path to the second antenna.

~~8.~~7. The mobile device of claim 1 wherein the first front end system is a cellular front end system and the second front end system is a WiFi front end system.

~~9.~~8. The mobile device of claim 1 wherein the first front end system is a WiFi front end system and the second front end system is a cellular front end system.

~~10.~~9. The mobile device of claim 1 wherein the second transceiver is configured to compensate a second baseband receive signal for radio frequency signal leakage based on additional digital observation data from the first transceiver.

~~11.~~10. The mobile device of claim ~~10~~ 9 wherein the first transceiver is configured to receive a sensed radio frequency signal from a directional coupler of the first front end system, and to process the sensed radio frequency signal to generate the additional digital observation data provided to the second transceiver.

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

~~13.~~12. The mobile device of claim 11 wherein the first front end system includes a duplexer and a power amplifier, the 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;

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

a baseband sampling circuit configured to sample the digital observation signal to generate first digital observation data;

an output configured to output the first digital observation data;

an input configured to receive second digital observation data; and

a discrete time cancellation circuit configured to compensate the digital baseband receive signal for radio frequency signal leakage based on the second digital observation data, the discrete time cancellation circuit including a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the second digital observation data.

~~15. The transceiver of claim 14 wherein the discrete time cancellation circuit includes a spectral regrowth modeling circuit configured to estimate an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the second digital observation data.~~

~~16.~~14. The transceiver of claim ~~15~~ 13 wherein the spectral regrowth modeling circuit is configured to estimate the amount of aggressor spectral regrowth based on modeling adjacent channel leakage ratio using predistortion.

~~17.~~15. A method of coexistence management in a mobile device, the method comprising:

providing a radio frequency receive signal from a first front end system to a first transceiver;

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

compensating the first digital baseband receive signal for radio frequency signal leakage based on digital observation data using a discrete time cancellation circuit of the first transceiver, including estimating an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data using a spectral regrowth modeling circuit;

generating a radio frequency observation signal based on observing a radio frequency transmit signal using a second front end system; and

processing the radio frequency observation signal to generate the digital observation data using a second transceiver.

~~18.~~16. The method of claim ~~17~~ 15 further comprising providing the digital observation data from the second transceiver to the first transceiver.

~~19. The method of claim 17 wherein compensating the first digital baseband receive signal includes estimating an amount of aggressor spectral regrowth present in the radio frequency receive signal based on the digital observation data using a spectral regrowth modeling circuit.~~

~~20.~~17. The method of claim ~~19~~ 15 wherein estimating the amount of aggressor spectral regrowth includes modeling adjacent channel leakage ratio using predistortion.