DESCRIPTION

Title Of Invention: APPARATUS AND METHODS FOR BIASING OF LOW NOISE AMPLIFIERS

BACKGROUND

Technical Field

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

Description of Related Technology

[0002] A low noise amplifier (LNA) can be used to boost the amplitude of a relatively weak radio frequency (RF) signal received via an antenna. Thereafter, the boosted RF signal can be used for a variety of purposes, including, for example, driving a switch, a mixer, and/or a filter in an RF communication system.

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

[0004] LNAs can be included in RF communication systems to amplify signals of a wide range of frequencies. For example, an LNA can be used to provide low noise amplification to RF signals in a frequency range of about 30 kHz to 300 GHz, such as in the range of about 400 MHz to about 7.125 GHz for Frequency Range 1 (FR1) of the Fifth Generation (5G) communication standard or in the range of about 24.250 GHz to about 71.000 GHz for Frequency Range 2 (FR2) of the 5G communication standard.

SUMMARY

[0005] In certain examples, the present disclosure relates to a mobile device. The mobile device includes an antenna and a front-end system that includes a low noise amplifier including at least one amplification transistor configured to amplify a radio frequency input signal received from the antenna, and a biasing circuit including a current bias circuit configured to generate a bias current based on a reference current and a voltage bias circuit configured to generate at least one input bias voltage for the at least one amplification transistor

based on the bias current. The current bias circuit includes a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor.

[0005a] In an aspect, the present disclosure refers to a mobile device comprising:

an antenna; and

a front-end system that includes a low noise amplifier including a common source transistor configured to amplify a radio frequency input signal received from the antenna, and a biasing circuit including a current bias circuit configured to generate a bias current based on a reference current and a voltage bias circuit configured to generate a gate bias voltage for a gate of the common source transistor based on the bias current, the current bias circuit including a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor configured to generate the gate bias voltage.

[0005b] In an aspect, the present disclosure refers to a low noise amplifier comprising:

a common source transistor configured to amplify a radio frequency input signal; and

a biasing circuit including a current bias circuit configured to generate a bias current

based on a reference current and a voltage bias circuit configured to generate a gate bias voltage for a gate of the common source transistor based on the bias current, the current bias circuit including a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor configured to generate the gate bias voltage.

[0005c] In an aspect, the present disclosure refers to a method of radio frequency signal amplification, the method comprising:

amplifying a radio frequency input signal using a common source transistor of a low noise amplifier;

generating a gate bias voltage of the common source transistor based on a bias current using a voltage bias circuit of the low noise amplifier; and

generating the bias current based on a reference current using a current bias circuit of the low noise amplifier, including receiving the reference current using a first bias transistor, generating the bias current using a second bias transistor, and controlling a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor using an amplifier, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor generating the gate bias voltage.

[0006] In various examples, the current bias circuit further includes a plurality of selection switches and a plurality of current mirroring transistors each selectable by a corresponding one of the plurality of selection switches, the plurality of current mirroring transistors biased by the second bias voltage.

[0007] In several examples, the first bias transistor includes a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor includes a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier.

[0008] In some examples, the at least one amplification transistor includes a common source transistor, and the at least one input bias voltage includes a gate bias voltage for the common source transistor. According to a number of examples, the biasing circuit includes a bias resistor and a bias resistor bypass switch, the voltage bias circuit configured to provide the gate bias voltage to a gate of the common source transistor through a parallel combination of the bias resistor and the bias resistor bypass switch. In accordance with various examples, the at least one amplification transistor further includes a cascode transistor in series with the common source transistor, and the at least one input bias voltage further includes a cascode bias voltage for the cascode transistor.

[0009] In several examples, the front-end systems further includes a controllable current source configured to generate the reference current, the controllable current source configured to control the reference current based on a gain control signal.

[0010] In various examples, the voltage bias circuit further includes a first voltage bias transistor and a resistor in series between a supply voltage and a ground voltage, and a second voltage bias transistor and a third voltage bias transistor in series between a gate of the first voltage bias transistor and the ground voltage. According to a number of examples, the voltage bias circuit is configured to generate a first input bias voltage of the at least one input bias voltage based on a voltage across the resistor, and to generate a second

input bias voltage of the at least one input bias voltage based on a gate voltage of the second voltage bias transistor.

[0011] In certain examples, the present disclosure relates to a low noise amplifier includes at least one amplification transistor configured to amplify a radio frequency input signal, and a biasing circuit including a current bias circuit configured to generate a bias current based on a reference current and a voltage bias circuit configured to generate at least one input bias voltage for the at least one amplification transistor based on the bias current. The current bias circuit including a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor.

[0012] In various examples, the current bias circuit further includes a plurality of selection switches and a plurality of current mirroring transistors each selectable by a corresponding one of the plurality of selection switches, the plurality of current mirroring transistors biased by the second bias voltage.

[0013] In several examples, the first bias transistor includes a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor includes a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier.

[0014] In some examples, the at least one amplification transistor includes a common source transistor, and the at least one input bias voltage includes a gate bias voltage for the common source transistor. According to a number of examples, the biasing circuit includes a bias resistor and a bias resistor bypass switch, the voltage bias circuit configured to provide the gate bias voltage to a gate of the common source transistor through a parallel combination of the bias resistor and the bias resistor bypass switch. In accordance with several examples, the at least one amplification transistor further includes a cascode transistor in series with the common source transistor, and the at least one input bias voltage further includes a cascode bias voltage for the cascode transistor.

[0015] In various examples, the low noise amplifier further includes a controllable current source configured to generate the reference current, the controllable current source configured to control the reference current based on a gain control signal.

[0016] In several examples, the voltage bias circuit includes a first voltage bias transistor and a resistor in series between a supply voltage and a ground voltage, and a second voltage bias transistor and a third voltage bias transistor in series between a gate of the first voltage bias transistor and the ground voltage. According to a number of embodiments, the voltage bias circuit is configured to generate a first input bias voltage of the at least one input bias voltage based on a voltage across the resistor, and to generate a second input bias voltage of the at least one input bias voltage based on a gate voltage of the second voltage bias transistor.

[0017] In certain examples, the present disclosure relates to a method of radio frequency signal amplification. The method includes amplifying a radio frequency input signal using at least one amplification transistor of a low noise amplifier, generating at least one input bias voltage for the at least one amplification transistor based on a bias current using a voltage bias circuit of the low noise amplifier, and generating the bias current based on a reference current using a current bias circuit of the low noise amplifier, including receiving the reference current using a first bias transistor, generating the bias current using a second bias transistor, and controlling a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor using an amplifier.

[0018] In some examples, controlling the first bias voltage of the first bias transistor to match the second bias voltage of the second bias transistor includes controlling a drain-to-source voltage of the first bias transistor to substantially equal a drain-to-source voltage of the second bias transistor.

[0019] In several examples, generating the at least one input bias voltage for the at least one amplification transistor including generating a gate bias voltage for a common source transistor and generating a cascode bias voltage for a cascode transistor that is in series with the common source transistor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] Embodiments of this disclosure will now be described, by way of non-limiting example, with reference to the accompanying drawings.

[0021] Figure 1 is a schematic diagram of one example of a communication network.

WHAT IS CLAIMED IS:

1. A mobile device comprising:

an antenna; and

a front-end system that includes a low noise amplifier including a common source transistor configured to amplify a radio frequency input signal received from the antenna, and a biasing circuit including a current bias circuit configured to generate a bias current based on a reference current and a voltage bias circuit configured to generate a gate bias voltage for a gate of the common source transistor based on the bias current, the current bias circuit including a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor configured to generate the gate bias voltage.

2. The mobile device of claim 1 wherein the current bias circuit further includes a plurality of selection switches and a plurality of current mirroring transistors each selectable by a corresponding one of the plurality of selection switches, the plurality of current mirroring transistors biased by the second bias voltage.

3. The mobile device of claim 1 wherein the biasing circuit includes a bias resistor and a bias resistor bypass switch, the voltage bias circuit configured to provide the gate bias voltage to the gate of the common source transistor through a parallel combination of the bias resistor and the bias resistor bypass switch.

4. The mobile device of claim 1 wherein the low noise amplifier further includes a cascode transistor in series with the common source transistor, the voltage bias circuit further configured to generate a cascode bias voltage for a gate of the cascode transistor.

5. The mobile device of claim 1 wherein the front-end system further includes a controllable current source configured to generate the reference current, the controllable current source configured to control the reference current based on a gain control signal.

6. The mobile device of claim 6 wherein the voltage bias circuit further includes a second voltage bias transistor and a third voltage bias transistor in series between a gate of the first voltage bias transistor and the ground voltage.

7. The mobile device of claim 6 wherein the voltage bias circuit is configured to generate the cascode bias voltage based on a gate voltage of the second voltage bias transistor.

8. A low noise amplifier comprising:

a common source transistor configured to amplify a radio frequency input signal; and

a biasing circuit including a current bias circuit configured to generate a bias current based on a reference current and a voltage bias circuit configured to generate a gate bias voltage for a gate of the common source transistor based on the bias current, the current bias circuit including a first bias transistor configured to receive the reference current, a second bias transistor configured to generate the bias current, and an amplifier configured to control a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor configured to generate the gate bias voltage.

9. The low noise amplifier of claim 8 wherein the current bias circuit further includes a plurality of selection switches and a plurality of current mirroring transistors each selectable by a corresponding one of the plurality of selection switches, the plurality of current mirroring transistors biased by the second bias voltage.

10. The low noise amplifier of claim 8 wherein the biasing circuit includes a bias resistor and a bias resistor bypass switch, the voltage bias circuit configured to provide the gate bias voltage to the gate of the common source transistor through a parallel combination of the bias resistor and the bias resistor bypass switch.

11. The low noise amplifier of claim 8 further comprising a cascode transistor in series with the common source transistor, the voltage bias circuit further configured to generate a cascode bias voltage for a gate of the cascode transistor.

12. The low noise amplifier of claim 8 further comprising a controllable current source configured to generate the reference current, the controllable current source configured to control the reference current based on a gain control signal.

13. The low noise amplifier of claim 11 wherein the voltage bias circuit further includes a second voltage bias transistor and a third voltage bias transistor in series between a gate of the first voltage bias transistor and the ground voltage.

14. The low noise amplifier of claim 13 wherein the voltage bias circuit is configured to generate the cascode bias voltage based on a gate voltage of the second voltage bias transistor.

15. A method of radio frequency signal amplification, the method comprising:

amplifying a radio frequency input signal using a common source transistor of a low noise amplifier;

generating a gate bias voltage of the common source transistor based on a bias current using a voltage bias circuit of the low noise amplifier; and

generating the bias current based on a reference current using a current bias circuit of the low noise amplifier, including receiving the reference current using a first bias transistor, generating the bias current using a second bias transistor, and controlling a first bias voltage of the first bias transistor to match a second bias voltage of the second bias transistor using an amplifier, the first bias transistor including a drain connected to a first input of the amplifier and a gate connected to an output of the amplifier, and the second bias transistor including a drain connected to a second input of the amplifier and a gate connected to the output of the amplifier, the voltage bias circuit including a first voltage bias transistor, a first resistor connected between the second input of the amplifier and a gate of the first voltage bias transistor, and a second resistor connected between a source of the first voltage bias transistor and a ground voltage, the source of the first voltage bias transistor generating the gate bias voltage.

16. The method of claim 15 further comprising generating a cascode bias voltage for a cascode transistor that is in series with the common source transistor.

17. The mobile device of claim 1 wherein the first bias transistor further includes a source connected to a supply voltage, and the second bias transistor further includes a source connected to a supply voltage.

18. The low noise amplifier of claim 8 wherein the first bias transistor further includes a source connected to a supply voltage, and the second bias transistor further includes a source connected to a supply voltage.

19. The method of claim 16 wherein the voltage bias circuit further includes a second voltage bias transistor and a third voltage bias transistor in series between a gate of the first

voltage bias transistor and the ground voltage, the method further comprising generating the cascode bias voltage based on a gate voltage of the second voltage bias transistor.

20. The method of claim 15 wherein the biasing circuit includes a bias resistor and a bias resistor bypass switch, the method further comprising providing the gate bias voltage to the gate of the common source transistor through a parallel combination of the bias resistor and the bias resistor bypass switch.