LOAD MODULATED POWER AMPLIFIERS

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] Power amplifiers are used in RF communication systems to amplify RF signals for transmission via antennas.

[0003] Examples of RF communication systems with one or more power amplifiers include, but are not limited to, mobile phones, tablets, base stations, network access points, customer-premises equipment (CPE), laptops, and wearable electronics. For example, in wireless devices that communicate using a cellular standard, a wireless local area network (WLAN) standard, and/or any other suitable communication standard, a power amplifier can be used for RF signal amplification. RF signals have a frequency in the range from about 30 kHz to 300 GHz, for instance, 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

[0004] In one aspect, the present disclosure relates to a mobile device. The mobile device includes a transceiver configured to generate a radio frequency signal and an envelope signal that changes in relation to an envelope of the radio frequency signal, and a front end system including a load modulated power amplifier configured to amplify the radio frequency signal. The load modulated power amplifier includes a power amplifier configured to receive the radio frequency signal at an input and to provide an amplified radio frequency signal at an output, and a controllable load impedance coupled to the output of the power amplifier. The envelope signal is operable to control an impedance of the controllable load impedance to modulate a load at the output of the power amplifier. The controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first

winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor. The second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

[0005] In various examples, the transceiver includes a shaping circuit configured to shape the envelope signal based on calibration data. According to a number of examples, the shaping circuit is operable to provide a flat gain versus input power characteristic to the power amplifier.

[0006] According to a number of examples, the power amplifier includes an input balun and a pair of amplifiers coupled between the input balun and the output balun. According to some examples, the controllable capacitor includes a bipolar transistor and a load capacitor coupled to a collector of the bipolar transistor, the envelope signal operable to control a base of the bipolar transistor. In accordance with a number of examples, the controllable load impedance includes a series combination of an inductor and a controllable capacitor having a capacitance controlled by the envelope signal.

[0007] In various examples, the mobile device further includes an antenna operable to transmit the amplified radio frequency signal.

[0008] In another aspect, the present disclosure relates to a load modulated power amplifier system. The load modulated power amplifier system includes a power amplifier configured to receive a radio frequency signal at an input, and to provide an amplified radio frequency signal at an output. The load modulated power amplifier system further includes a controllable load impedance coupled to the output of the power amplifier and configured to receive an envelope signal that changes in relation to an envelope of the radio frequency signal. The envelope signal is operable to control an impedance of the controllable load impedance to modulate a load at the output of the power amplifier. The controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor. The second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

[0009] According a number of examples, the power amplifier includes an input balun and a pair of amplifiers coupled between the input balun and the output balun.

According to some examples, the controllable capacitor includes a bipolar transistor and a load capacitor coupled to a collector of the bipolar transistor, the envelope signal operable to control a base of the bipolar transistor.

[0010] In various examples, the controllable load impedance includes a series combination of an inductor and a controllable capacitor having a capacitance controlled by the envelope signal.

[0011] In another aspect, the present disclosure relates to a method of amplification in a mobile device. The method includes generating a radio frequency signal and an envelope signal that changes in relation to an envelope of the radio frequency signal using a transceiver. The method further includes amplifying the radio frequency signal using a power amplifier, including receiving the radio frequency signal at an input to the power amplifier and providing an amplified radio frequency signal at an output of the power amplifier. The method further includes modulating a load of the power amplifier by using the envelope signal to control an impedance of a controllable load impedance coupled to the output of the power amplifier. The controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor. The second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

[0012] In various examples, the method further includes calibrating the power amplifier by shaping the envelope signal based on calibration data. According to a number of examples, calibrating the power amplifier includes providing a flat gain versus input power characteristic.

[0013] In several examples, modulating the load of the power amplifier includes controlling a capacitance of a controllable capacitor that is coupled to an output balun. According to a number of examples, the method further includes providing the amplified radio frequency signal to a first winding of the output balun, the controllable capacitor coupled to a second winding of the output balun.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Embodiments of this disclosure will now be described, by way of non-limiting example, with reference to the accompanying drawings.

WHAT IS CLAIMED IS:

1. A mobile device comprising:

a transceiver configured to generate a radio frequency signal and an envelope signal that changes in relation to an envelope of the radio frequency signal; and

a front end system including a load modulated power amplifier configured to amplify the radio frequency signal, the load modulated power amplifier including a power amplifier configured to receive the radio frequency signal at an input and to provide an amplified radio frequency signal at an output, and a controllable load impedance coupled to the output of the power amplifier, the envelope signal operable to control an impedance of the controllable load impedance to modulate a load at the output of the power amplifier,

wherein the controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor, and

wherein the second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

2. The mobile device of claim 1 wherein the transceiver includes a shaping circuit configured to shape the envelope signal based on calibration data.

3. The mobile device of claim 2 wherein the shaping circuit is operable to provide a flat gain versus input power characteristic to the power amplifier.

4. The mobile device of claim 1 wherein the power amplifier includes an input balun and a pair of amplifiers coupled between the input balun and the output balun.

5. The mobile device of claim 1 wherein the controllable capacitor includes a bipolar transistor and a load capacitor coupled to a collector of the bipolar transistor, the envelope signal operable to control a base of the bipolar transistor.

6. The mobile device of claim 1 wherein the controllable load impedance includes a series combination of an inductor and a controllable capacitor having a capacitance controlled by the envelope signal.

7. The mobile device of claim 1 further comprising an antenna operable to transmit the amplified radio frequency signal.

8. A load modulated power amplifier system comprising:

a power amplifier configured to receive a radio frequency signal at an input, and to provide an amplified radio frequency signal at an output; and

a controllable load impedance coupled to the output of the power amplifier and configured to receive an envelope signal that changes in relation to an envelope of the radio frequency signal, the envelope signal operable to control an impedance of the controllable load impedance to modulate a load at the output of the power amplifier,

wherein the controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor, and

wherein the second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

9. The load modulated power amplifier system of claim 8 wherein the power amplifier includes an input balun and a pair of amplifiers coupled between the input balun and the output balun.

10. The load modulated power amplifier system of claim 8 wherein the controllable capacitor includes a bipolar transistor and a load capacitor coupled to a collector of the bipolar transistor, the envelope signal operable to control a base of the bipolar transistor.

11. The load modulated power amplifier system of claim 8 wherein the controllable load impedance includes a series combination of an inductor and a controllable capacitor having a capacitance controlled by the envelope signal.

12. A method of amplification in a mobile device, the method comprising:

generating a radio frequency signal and an envelope signal that changes in relation to an envelope of the radio frequency signal using a transceiver;

amplifying the radio frequency signal using a power amplifier, including receiving the radio frequency signal at an input to the power amplifier and providing an amplified radio frequency signal at an output of the power amplifier; and

modulating a load of the power amplifier by using the envelope signal to control an impedance of a controllable load impedance coupled to the output of the power amplifier,

wherein the controllable load impedance includes a controllable capacitor controlled by the envelope signal and an output balun having a first winding coupled to the output of the power amplifier and a second winding coupled to the controllable capacitor, and

wherein the second winding includes a first terminal that outputs the amplified radio frequency signal and a second terminal coupled to the controllable capacitor.

13. The method of claim 12 further comprising calibrating the power amplifier by shaping the envelope signal based on calibration data.

14. The method of claim 10 wherein calibrating the power amplifier includes providing a flat gain versus input power characteristic.

15. The method of claim 12 wherein modulating the load of the power amplifier includes controlling a capacitance of a controllable capacitor that is coupled to an output balun.

16. The method of claim 15 further comprising providing the amplified radio frequency signal to a first winding of the output balun, the controllable capacitor coupled to a second winding of the output balun.