

WHAT IS CLAIMED IS:

1. An envelope tracking system comprising:
 - a power amplifier configured to amplify a radio frequency signal and to receive power from a power amplifier supply voltage; and
 - an envelope tracker configured to generate the power amplifier supply voltage based on an envelope signal corresponding to an envelope of the radio frequency signal, the envelope tracker including a DC-to-DC converter configured to output a plurality of regulated voltages, a modulator configured to control the power amplifier supply voltage based on the plurality of regulated voltages and the envelope signal, and a switching point adaptation circuit configured to control a voltage level of at least one of the plurality of regulated voltages based on a power level of the radio frequency signal.
2. The envelope tracking system of claim 1 wherein the switching point adaptation circuit is configured to control the voltage level of each of the plurality of regulated voltages based on the power level of the radio frequency signal.
3. The envelope tracking system of claim 1 wherein the switching point adaptation circuit includes a power estimation circuit configured to estimate the power level of the radio frequency signal based on a signal power value for at least one of a transmit frame or a transmit symbol.
4. The envelope tracking system of claim 3 wherein the signal power value indicates an average power.
5. The envelope tracking system of claim 3 wherein the signal power value indicates a peak power.
6. The envelope tracking system of claim 3 wherein the switching point adaptation circuit further includes a voltage estimation circuit configured to estimate a plurality of desired voltage levels associated with the signal power value.

7. The envelope tracking system of claim 6 wherein the switching point adaptation circuit further includes a programming circuit configured to control the DC-to-DC converter to output the plurality of regulated voltages each with a corresponding one of the plurality of desired voltage levels.

8. The envelope tracking system of claim 1 comprising two or more power amplifiers configured to amplify two or more radio frequency signals, the envelope tracker including two or more modulators each configured to receive the plurality of regulated voltages and to provide modulation to generate a supply voltage for a corresponding one of the two or more power amplifiers.

9. The envelope tracking system of claim 8 wherein the switching point adaptation circuit is configured to control the voltage level based on a largest power level of the two or more radio frequency signals.

10. The envelope tracking system of claim 1 wherein each of the plurality of regulated voltages has a different voltage level.

11. The envelope tracking system of claim 1 wherein the modulator includes a plurality of switches each coupled between an output of the modulator and a corresponding one of the plurality of regulated voltages.

12. The envelope tracking system of claim 1 further comprising a modulator output filter connected between an output of the modulator and the power amplifier supply voltage, the modulator output filter includes at least one series inductor and at least one shunt capacitor.

13. A mobile device comprising:

a transceiver configured to generate a radio frequency transmit signal;

a front end circuit including a power amplifier configured to amplify the radio frequency transmit signal and to receive power from a power amplifier supply voltage; and

a power management circuit including an envelope tracker configured to generate the power amplifier supply voltage based on an envelope signal corresponding to an envelope of the radio frequency transmit signal, the envelope tracker including a DC-to-DC converter configured to output a plurality of regulated voltages, a modulator configured to control the power amplifier supply voltage based on the plurality of regulated voltages and the envelope signal, and a switching point adaptation circuit configured to control a voltage level of at least one of the plurality of regulated voltages based on a power level of the radio frequency transmit signal.

14. The mobile device of claim 13 wherein the switching point adaptation circuit includes a power estimation circuit configured to estimate the power level of the radio frequency transmit signal based on a signal power value for at least one of a transmit frame or a transmit symbol.

15. The mobile device of claim 14 wherein the switching point adaptation circuit further includes a voltage estimation circuit configured to estimate a plurality of desired voltage levels associated with the signal power value.

16. The mobile device of claim 15 wherein the switching point adaptation circuit further includes a programming circuit configured to control the DC-to-DC converter to output the plurality of regulated voltages each with a corresponding one of the plurality of desired voltage levels.

17. The mobile device of claim 13 comprising two or more power amplifiers configured to amplify two or more radio frequency transmit signals, the envelope tracker including two or more modulators each configured to receive the plurality of regulated voltages and to provide modulation to generate a supply voltage for a corresponding one of the two or more power amplifiers.

18. The mobile device of claim 17 wherein the switching point adaptation circuit is configured to control the voltage level based on a largest power level of the two or more radio frequency transmit signals.

19. A method of envelope tracking, the method comprising:
 amplifying a radio frequency signal using a power amplifier;
 supplying power to the power amplifier using a power amplifier supply voltage;
 outputting a plurality of regulated voltages from a DC-to-DC converter;
 controlling the power amplifier supply voltage based on the plurality of regulated voltages and an envelope signal using a modulator, the envelope signal corresponding to an envelope of the radio frequency signal; and
 controlling a voltage level of at least one of the plurality of regulated voltages based on a power level of the radio frequency signal.

20. The method of claim 19 further comprising estimating the power level of the radio frequency signal based on a signal power value for at least one a transmit frame or a transmit symbol, and estimating a plurality of desired voltage levels associated with the signal power value.