Envelope Tracking Technology

MediaTek White Paper

January 2015

Introduction

This white paper introduces MediaTek's innovative Envelope Tracking technology found today in MediaTek SoCs. MediaTek has developed wireless communication platforms that are able to support envelope tracking systems with external supply modulators and GaAs or CMOS power amplifiers.

Why the Need for Envelope Tracking Technology

Due to the rapid evolution of wireless technology and the increasing demand for higher data rates, modulation schemes employed in wireless communications are becoming more complicated. These complex modulation schemes generate transmit signals with high peak-to-average power ratios (PAPR) which degrade the efficiency of RF power amplifiers (amplifiers). The situation becomes more severe when more bands are required in long-term evolution (LTE) services. RF Amplifiers tend to function less efficiently when they are configured to cover a wider frequency range. Furthermore, LTE Advanced (LTE-A) services with carrier aggregation (CA) command more complicated RF front-end components that are accompanied with more insertion losses, pushing RF Amplifiers to output higher power, which may exceed the capacity of conventional RF Amplifiers with fixed supply voltage. The Envelope Tracking technique was designed to address this problem, and is regarded as one of the most promising efficiency improvement technologies. By instantaneously adjusting the amplifier supply voltage according to the envelope of the modulated signal, Envelope Tracking can effectively reduce the power consumption of the amplifier and hence significantly improve the overall system efficiency.

Recognizing its efficiency improvement ability, many world-leading companies have adopted Envelope Tracking to their flagship LTE smartphones, including Apple, Samsung, LG, HTC, Sony, ZTE, and Amazon. Envelope Tracking is also useful to improve linearity and efficiency of CMOS power amplifiers that are widely used in WiFi applications. Therefore, it is recognized that Envelope Tracking technology will play an essential role in the next generation of high data-rate wireless communications.

Concept of Envelope Tracking

Figure 1 presents a simplified block diagram of a conventional RF power amplifier. The fixed supply voltage is set high enough to linearly amplify high PAPR signals. However, a large portion of the supplied energy is dissipated as heat when the instantaneous power is lower than the peak power. Thus, the conventional RF amplifier operates at low efficiency for most of the time. Instead of driving the amplifier with a fixed supply voltage for all transmissions, average-power-tracking adaptively changes the supply voltage for amplifier according to the average power during a certain time frame. By varying the supply voltage in a frame basis, the amplifier is driven with better efficiency especially when delivering lower output power.

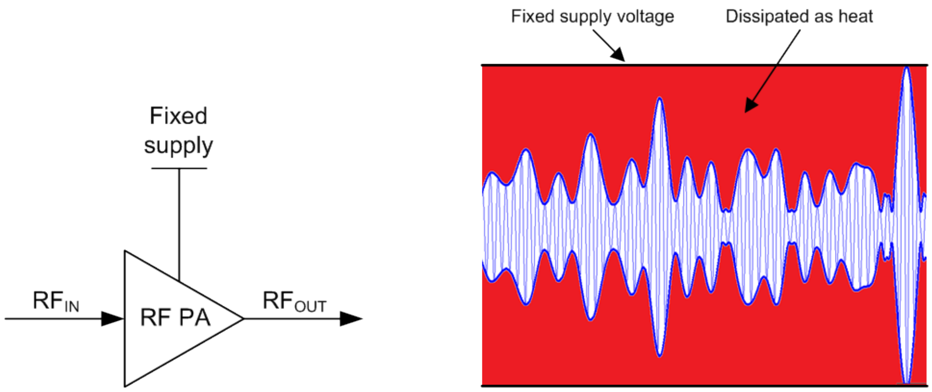


Figure 1. Conventional Power Amplifier with Fixed Supply Voltage

In Figure 2 below, the Envelope Tracking architecture consists of a supply modulator and an RF amplifier. The supply modulator dynamically adjusts the supply voltage of the RF amplifier according to the envelope of the transmitted signal. The efficiency of RF amplifier at each instantaneous sample is improved because less energy is dissipated by properly selecting the supply voltage for each instantaneous output power level. As a result, the RF amplifier operates with high efficiency for all power levels. While Envelope Tracking can significantly improve amplifier efficiency, it requires the supply modulator to provide modulated supply voltage, whose bandwidth is often much wider than that in APT. Consequently, the supply modulator might be less efficient than the conventional DC-DC buck converter used in APT. As the overall efficiency is concerned, i.e. taking both amplifier and the supply modulator into account, Envelope Tracking is often configured to operate at a higher TX power range where amplifier has much more significant efficiency improvement.

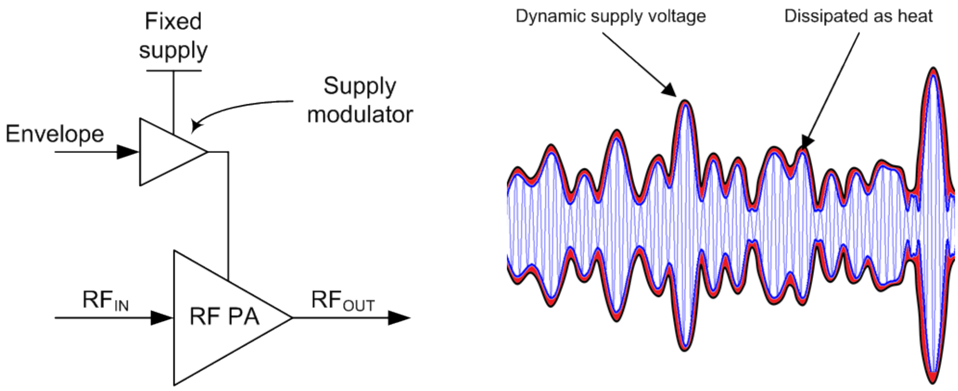


Figure 2. Envelope Tracking Power Amplifier with Dynamic Supply Voltage

MediaTek Envelope Tracking Systems

MediaTek's wireless communication platforms support envelope tracking systems with external supply modulators and GaAs or CMOS amplifiers. The main block diagram of an Envelope Tracking system is shown below. The upper portion is the Envelope Tracking path while the lower portion corresponds to the normal TX path. The Envelope Tracking path contains digital and analog sections. In the digital section, the IQ signal is transformed into an envelope signal through the envelope detector block. Then the envelope signal is scaled according to the target antenna output power in the power scaling block. The Vpa look-up-table (LUT) mapper converts the scaled envelope signal into the corresponding amplifier supply voltage. In the analog section, the supply modulator is responsible for providing the modulated supply voltage to the power amplifier.

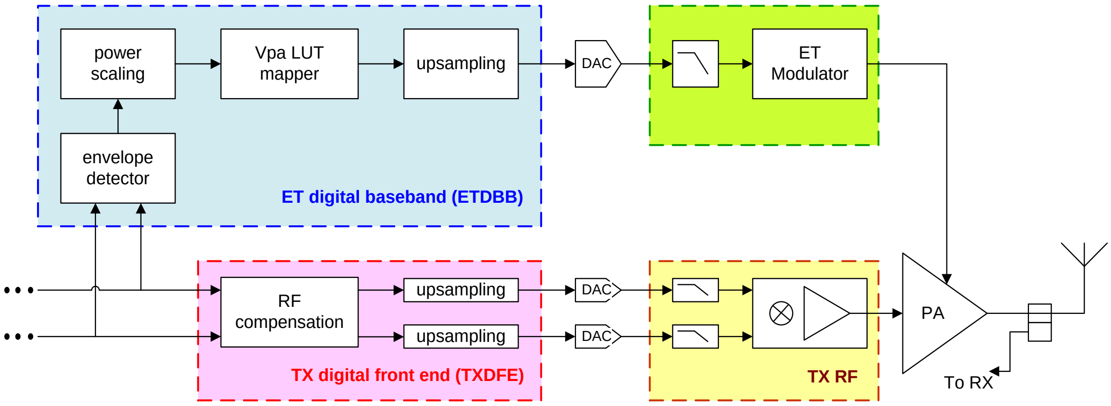
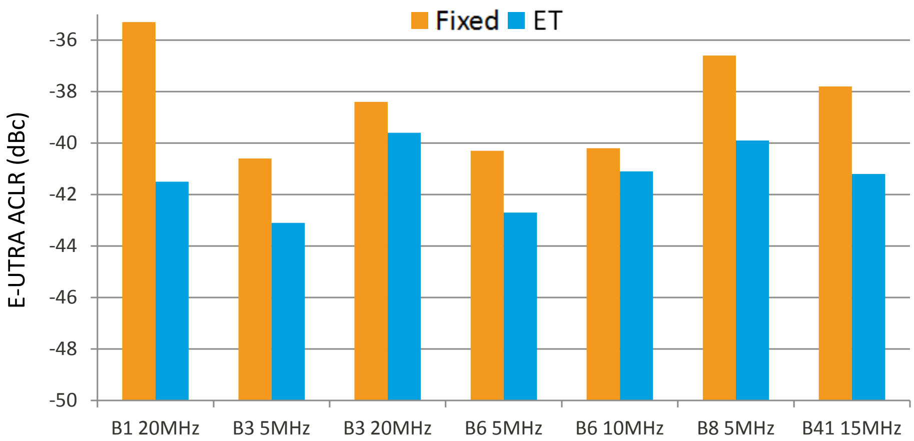


Figure 3. MediaTek's Envelope Tracking System Block Diagram

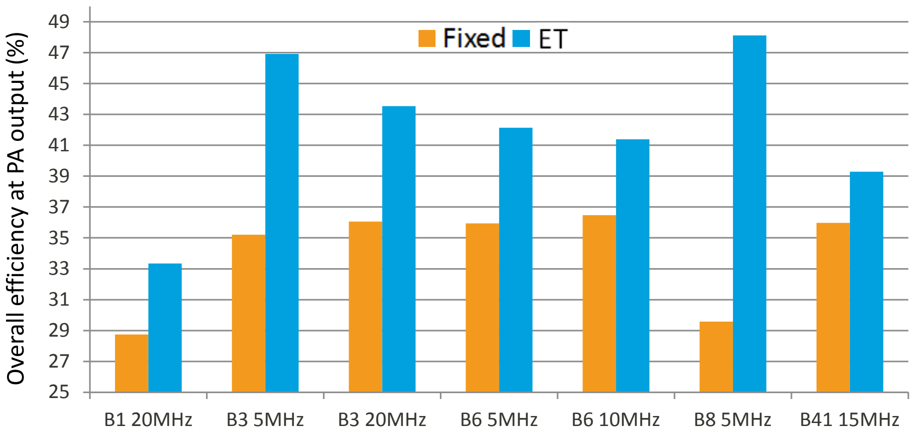
To fully exploit Envelope Tracking's advantages, MediaTek has developed robust and fast lab/factory calibration approaches for different RF amplifier models to combat process-voltage-temperature (PVT) variations. There are two major objectives in Envelope Tracking factory calibration. The first is to configure a Vpa look-up-table (LUT) characterizing the integrated amplifier based on pre-defined design criteria. Timing misalignment between the TX signal and the envelope signal may cause distortion of the amplifier output signal and lead to spectrum emission and/or error vector magnitude (EVM) degradation. The wider bandwidth the TX signal has, in general, the more sensitive it is to the timing mismatch. As a result, the second major objective is to detect the delay difference between the Envelope Tracking path and the TX path so that the timing alignment between these two paths can be guaranteed.

Moreover, amplifier characteristics are known to fluctuate with circuitry or environmental factors such as a load mismatch, a temperature shift, a VSWR change, device aging. Therefore, any changes in these factors may lead to linearity performance and power efficiency degradation of a wireless system. With the capability of self-recalibration during active transmission, MediaTek's advanced Envelope Tracking system promises to wisely adapt itself to a constantly varying operating condition and thus continuously drive the amplifier functioning efficiently.

To evaluate the Envelope Tracking performance, we compare the performances of a fixed-supply amplifier and an Envelope Tracking power amplifier with different channel bandwidths in the low, middle, and high LTE bands. Two types of RF amplifiers from amplifier vendors are implemented. One is for the LTE band 41, and the other is for the LTE bands 1, 3, 6, and 8. These amplifiers are operated at the center frequency of each LTE band. Figure 4 shows the measurement results at the maximum antenna output power level of 23 dBm. In terms of the E-UTRA adjacent channel leakage power ratio (ALCR) and the overall efficiency, the Envelope Tracking amplifier outperforms the fixed-supply amplifier in all LTE bands. The maximum efficiency improvement reaches around 18.5% with an LTE 5-MHz signal in the LTE band 8. Based on the measurement results, we show that the Envelope Tracking system can indeed achieve both high efficiency and good linearity.



(a)



(b)

Figure 4: Performance Comparison of Conventional PA and Envelope Tracking PA (a) E-UTRA ACLR and (b) Overall Efficiency

Conclusion

MediaTek's Envelope Tracking system for cellular applications is suitable for commonly used RF amplifiers and supply modulators. To achieve the best performance, both factory and on-the-fly calibrations are incorporated into the Envelope Tracking system. The measurement results demonstrate that the Envelope Tracking system can ensure both high efficiency and good linearity in all LTE bands. Hence, the Envelope Tracking system allows mobile devices to operate with many benefits, such as less heat dissipation, a longer battery lifetime, and better user experiences. Besides, because of the very high date rate which increases the PAPR of WiFi waveforms, we expect a much greater efficiency benefit of Envelope Tracking for 802.11ac WiFi than that for 4G. For the reason, the WiFi market will be another promising opportunity for Envelope Tracking.