The RF Sting in the Digital Transmission Tail

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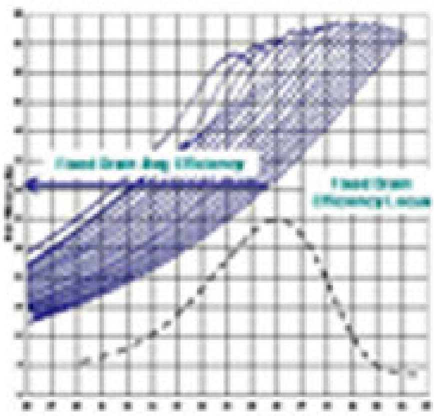
The new generation of data-oriented digital communications networks being rolled out in the cellular, broadcast, military and other environments carries a sting in the tail for RF designers. In order to achieve high data rates, these new standards use advanced modulation techniques such as OFDM which significantly increase the variations in amplitude of the transmitted signal.

Although baseband and RF technology has already moved to flexible, Software Defined Radio platforms, the final PA stage, which consumes most of the power, remains narrowband and single mode.

RF power amplifiers are classic Class AB amplifiers, and offer efficient operation when the RF envelope waveform is close to peak power. When amplifying amplitude modulated RF signals with high crest factors, they are less efficient, typically in the range 15 to 25% for W-CDMA and WiMax. The reason for this is shown in Figure 1, where the solid blue curve represents drain efficiency vs. power output and the dashed curve is the probability distribution of instantaneous output power value. As can be seen, for much of the time the signal power lies well below the peak power and hence the device is operating at low efficiency. Similar graphs could be drawn for digital broadcast, JTRS and other 'new generation' digital transmissions.



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Despite the emergence of new technologies such as GaN, power amplifiers only deliver high efficiency over a fairly narrow bandwidth. Accepted power optimization techniques such as Doherty are also narrow band, and require careful hand-crafting to address each specific frequency band, operating mode and power level.

Envelope Tracking

In consequence, there has been renewed interest in envelope tracking, a technique for improving power efficiency of RF power amplifiers first described in the 1930s that is frequency and modulation scheme agnostic. Envelope Tracking adjusts the supply voltage to the power amplifier output transistor dynamically, in synchronism with the envelope of the modulated RF signal passing through the device. This ensures that the output device always remains in its most efficient operating region (i.e. in saturation) dramatically reducing the energy dissipated.

Figure 2 shows Envelope Tracking in operation. Without envelope tracking, the difference between the constant power into the RF amplifier and the RF output waveform is dissipated in the RF power transistor as heat. With envelope tracking, the supply voltage tracks the signal envelope, dramatically reducing the energy dissipated.

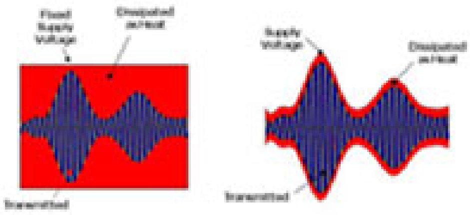

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Figure 2. Envelope tracking reduces the voltage difference between the supply voltage and the signal envelope, dramatically reducing the energy dissipated as heat.

Although the principles of Envelope Tracking have been known for some time, the practical difficulties of implementing a working system have prevented the concept from being employed until recently. The challenge is making a power supply modulator capable of achieving the accuracy, bandwidth and noise specifications necessary at a level of conversion efficiency that delivers a significant energy saving for the system as a whole.

Critical performance issues include tracking accuracy, modulator efficiency, stability, compliance with spurious-signal and noise specifications, and bandwidth for multi-carrier support. Nuijra was able to overcome these issues with High Accuracy Tracking (HAT™).

To retain compliance with demanding noise and spurious specification, the power modulator tracks the RF signal envelope with utmost accuracy in both timing and amplitude. It does so by calculating the amplitude from the digital signal (?($I^2 + Q^2$)) and applying a simple function to arrive at the optimum instantaneous drain voltage. In parallel, a delay is calculated and applied to the RF signal before it is input to the amplifier, cancelling out the delay in the modulator. Using this approach, Nujira has achieved efficiencies in excess of 60% for an 880 MHz LTE power amplifier, based on its commercially available Coolteq.h power modulator and Digital Pre Distortion (DPD) solution. These are the highest efficiencies ever achieved for an LTE signal.

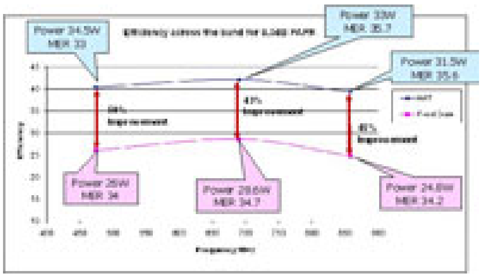

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Figure 3. This figure shows the level of energy efficiency improvement that can be obtained when using an envelope tracking HAT power modulator in a wide band UHF system.

The first customer-announced product is the Sumitomo GED21RUP001 radio head for WCDMA, HSPA and LTE applications, which uses a Nujira Coolteq.h module to deliver 40 W output from a unit weighing just 12 kg and measuring 324 mm x 341 mm x 173 mm.

HAT implementation is relatively straightforward. The only addition required to the standard PA architecture is an output from the DPD/Linearization function to drive the HAT Power Modulator with a digital representation of the modulation envelope, representing around 50k gates of digital logic. The power feed to the drain of the PA also requires careful layout to reduce impedance, and to remove any decoupling capacitors – the bandwidth of the modulator power supply is typically up to 3x the instantaneous bandwidth of the RF signal being transmitted.

Efficiency Improvement Across a Broad Bandwidth

Figure 3 shows the level of energy efficiency improvement that can be obtained when using an envelope tracking HAT power modulator in a wide band UHF system. It can be seen that the efficiency improvement exactly tracks the normal Class A/B “fixed drain” solution across the whole band, while maintaining strong linearity and providing some additional benefit in the form of increased power output from the transistor (due to thermal management improvement). The results were measured in the Nujira Laboratory and are a real example of the benefits that this technology offers.

Note that the efficiency enhancement is maintained across a very wide band – a characteristic of envelope tracking. This need to provide adequate linearity with enhanced efficiency over a wide band with high Peak to Average signals is exactly the type of challenge now facing designers for the next generation of digital communications networks.

It has been shown that that linearity with Envelope Tracking is actually intrinsically improved compared to Class A/B designs and these results can be achieved without the use of Digital Pre Distortion and the added system complexity that this would bring.

Conclusion

Momentum behind Envelope Tracking is growing, and the OpenET Alliance has now published a Terminal Interface specification on the web, allowing any device or terminal manufacturer to access and use the technology.

At Mobile World Congress in 2010, Texas Instruments announced that it had become the first to offer an envelope tracking port as standard on its digital pre-distortion (DPD) transmit processors and development boards.

Reference designs for envelope tracking based power amplifier (PA) platforms were also shown by RFMD, Triquint and Nujira. The technology is being evaluated by almost all of the major infrastructure vendors, broadcast transmitter manufacturers and the military, attracted by the potential of reduced operating costs and enhanced environmental credentials.

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