Digital Integrated Circuits and Systems

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Energy Efficient Ultra-wideband Radios

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Applications like sensor networks, medical monitoring, and asset tracking have led to a demand for energy-efficient and low-cost wireless transceivers. These types of applications typically require low effective data rates, thus providing an opportunity to employ simple modulation schemes and aggressive duty-cycling. Due to their inherently duty-cycled nature, pulsed-UWB systems have been shown to be amenable to low-power operation [1, 2]. Furthermore, the use of non-coherent signaling greatly simplifies both transmitter and receiver implementations, offering substantial energy savings [3].

This work presents an all-digital transmitter designed for a non-coherent pulsed-UWB system. By exploiting the fact that center frequency tolerances are relaxed in wideband non-coherent communication, the transmitter can synthesize UWB pulses from an energy-efficient, single-ended digital ring oscillator. To generate phase modulated pulses (which are required for spectral scrambling purposes), the oscillator output is fed to two banks of parallel tri-state inverters, shown in Figure 1. Maintaining opposite common modes at the output of these inverters during idle mode (i.e., when no pulses are being transmitted) eliminates low-frequency turn-on and turn-off transients typically associated with single-ended digital circuits driving single-ended antennas. Thus, no area-expensive balun is required to generate BPSK-modulated pulses. The parallel inverter banks permit digital pulse-shaping, resulting in on-chip FCC-compliant operation, as Figure 2 shows. The transmitter was fabricated in 90nm CMOS, consumes zero static bias current, and achieves an energy efficiency of 113-to-19pJ/pulse at data rates from 100kbps-to-15.6Mbps.

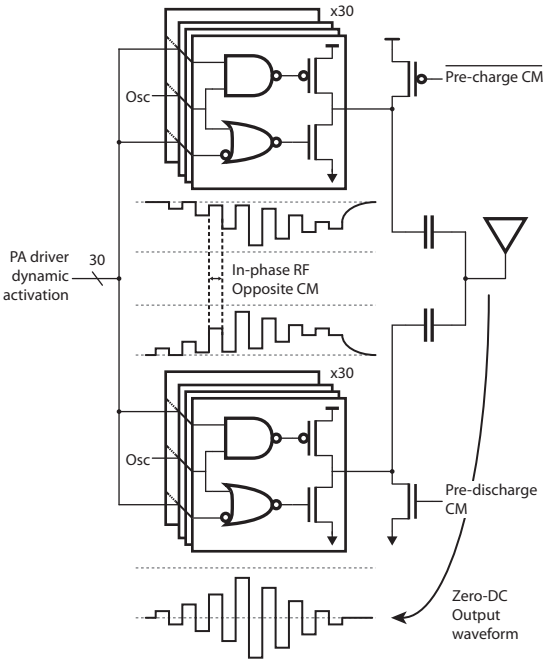

Figure 1: Dual-digital power amplifiers create a bi-polar (zero-DC) output pulse by combining paths that are in-phase at RF yet have counter-phase common-mode components that are cancelled.

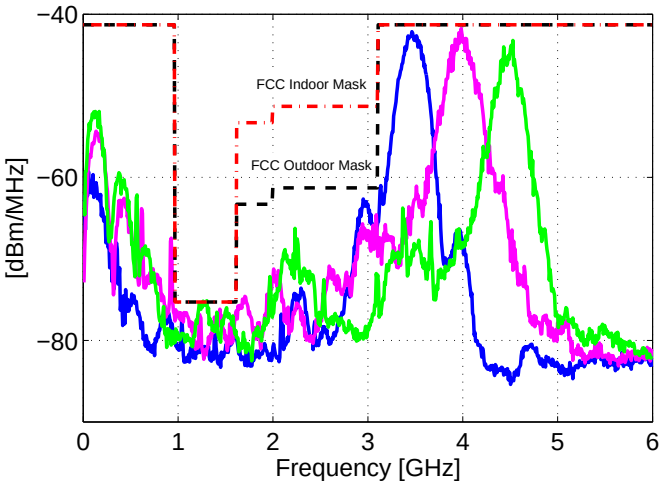

Figure 2: Output spectral densities in three channels, from 3.5-to-4.5 GHz, illustrating on-chip FCC compliance.

References:

[1] F.S. Lee and A.P. Chandrakasan, "A 2.5nJ/b 0.65V 3-to-5GHz Sub-banded UWB Receiver in 90nm CMOS," in *Proc. IEEE International Solid-State Circuits Conference*, Feb. 2007, pp. 116-117.

[2] D.D. Wentzloff and A.P. Chandrakasan, "A 47pJ/pulse 3.1-to-5GHz All-digital UWB Transmitter in 90nm CMOS," in Proc. *IEEE International Solid-State Circuits Conference*, Feb. 2007, pp. 118-119.

[3] L. Stoica, A. Rabbachin, H. Repo, S. Tiuraniemi, and I. Oppermann, “An ultra-wideband system architecture for tag-based wireless sensor networks,” *IEEE Transactions on Vehicular Technology*, vol. 54, pp. 1632-1645, Sep. 2005.

Publications

[1] P.P. Mercier, D.C. Daly, and A.P. Chandrakasan, “A 19pJ/pulse UWB Transmitter with Dual Capacitively-coupled Digital Power Amplifiers,” in *Proc. IEEE Radio Frequency Integrated Circuits Symposium*, Jun. 2008.

[2] P. P. Mercier, D. C. Daly, M. Bhardwaj, D. D. Wentzloff, F. S. Lee, and A. P. Chandrakasan, "Ultra-low-power UWB for sensor network applications", in *Proc. IEEE International Symp. on Circuits and Systems,* May 2008.