A 0.038mm² SAW-less Multiband Transceiver Using an N-Path SC Gain Loop

Gengzhen Oi,
Pui-In Mak,
Rui P. Martins

1University of Macau, Macau, China,
2Instituto Superior Tecnico, Lisbon, Portugal

N-path filtering has been intensely rekindled as a replacement of costly SAW filters, making possible of multiband blocker-tolerant receivers (Rxs) at small area and power, e.g., [1]. This paper proposes an N-Path Switched-Capacitor (SC) Gain Loop that is reconfigurable as an RF-fanable transmitter (TX) or RX with LO-defined center frequency. Comparatively, a SAW-less RX should be able to amplify a weak in-band (IB) signal in the presence of large out-of-band (OB) blockers, whereas a SAW-less TX should be able to deliver a large IB signal with low spectral leakage and OB noise. Such discrepancy inspires exploration of an RX-TX-compatible N-path technique to realize a multiband transceiver (TXR) with zero on-chip inductors and external matching components. Our TXR aims at the multiband LTE standard, and comparable performances are achieved at a die size 24x smaller than the recent art [2, 3].

The proposed SC-Gain Loop (Fig. 26.9.1a) is a negative-gain stage with an SC network as its feedback. Any signals, RF or BB, properly injected into the loop will undergo gain, downmix, and upmix, all are primary functions of TX or RX. Thus, the SC-gain loop can operate as a basic TX by injecting the BB signal while extracting the RF signal (Fig. 26.9.1b), or a basic RX by injecting the RF signal while extracting the BB signal (Fig. 26.9.1c). This duality suggests the possibility of using the SC-gain loop as a reconfigurable TXR appropriate for LTE-TDD.

To interface with the typical 4-phase BB signals (I/Q and differential) for quadrature modulation, a 4-path SC-gain loop can become a practical TX (Fig. 26.9.2). VRX,IB, are injected via passive-RC filters (RBT and CBT) that also suppress the OB noise of the BB sources (e.g., DACs). As the N-path filter (Cf and SWL,R) is created around the gain stage (GmRF), high-Q bandpass filtering is created at both VRX,IB and VRX,RF [4]. The loop gain offered by GmRF reduces the required size of Cf (8pF) thanks to the Miller multiplication effect, and decouples the size of SWL,R to the OB rejection (i.e., smaller LO power). Unlike the RX-only N-path solution in [1] that benefits from a large GmRF (200mS) to improve the NF and OB linearity, the concerns of spectral regrowth and EVM are limited by the RF BW (10MHz) and therefore the achieved OB-IIP3 (+8dBm) and OB-P1dB (-5dBm) are both competitive at 80MHz offset.

For the TX mode, the Pout shows -1dBm at 1.88GHz (Band2) after de-embedding the cable and PCB loss. The ACLR, (ACLRB) is -40dBc (-51.9dBc) (Fig. 29.6.5a) and EVM is 2.0%. The output noise floor is -154.5dBc/Hz at 80MHz offset and C1M, is -52dBc. The results are similar at 0.886GHZ (Band5) and are summarized in Fig. 29.6.6. High-Q bandpass characteristics are consistently measured at different RF, by simply sweeping the LO frequency (Fig. 29.6.5b). The TX-mode consumes 31.3mW (Band5) to 38.4mW (Band2) (Fig. 29.6.5c).

For the RX mode, the S11 is <–12dB. The NF is 2.2dB at Band5, and up to 3.2dB at Band2 limited by the bondwire effects. Unlike [1] that targets a narrow RF BW (2.7MHz), here the RF BW is much wider (10MHz) and therefore the achieved OB-P1dB (-5dBm) and OB-IIP3 (+8dBm) are both competitive at 80MHz offset. The 0dBm-blocker NF is 16dB at 80MHz offset.

Benchmarking with the recent LTE TXs [2, 3], our TRX in TX mode succeeds in creating multiband flexibility, while achieving a comparable TX efficiency at a much smaller die size. For our TRX in RX mode, similar NF and die size are achieved when comparing with [1], while this work operates at 1.25x higher RF and entails only a single supply (Fig. 29.6.7).

Acknowledgements:
The authors thank Macao FDCT and UM-MYRG2015-00040-FST for financial support and Dr. Zhicheng Lin for discussion on the receiver mode.

References:

ISSCC 2016 / SESSION 26 / WIRELESS FOR IoE / 26.9

452 • 2016 IEEE International Solid-State Circuits Conference 978-1-4673-9467-3/16/$31.00 ©2016 IEEE
Figure 26.9.1: a) SC-Gain Loop. It can operate as a) TX under BB-injection RF-extraction, or c) RX under RF-injection BB-extraction.

Figure 26.9.2: 4-Path SC-Gain Loop as a TX.

Figure 26.9.3: Simulated TX-mode performances at 2GHz: a) $V_{i,TX}$ and $V_{o,TX}$; b)-c) $R_{BT}$ controls the RF BW, stopband rejection and output noise; d) OB harmonics of $V_{RF,TX}$ at 0dBm output.

Figure 26.9.4: 4-path SC-Gain Loop as an RX.

Figure 26.9.5: a) Measured TX output spectrum for the LTE Band2 (1.88GHz); b) Bandpass responses centered at different LOs. c) Power breakdown at different RF frequencies.

Figure 26.9.6: Measured TX-mode performance comparison.
Figure 26.9.7: TXR die micrograph and its RX-mode performance comparison.