All Digital Frequency Synthesis Based on New Sigma-Delta Modulation Architectures

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This paper presents an overview of high dynamic range (DR) all-digital frequency synthesis techniques based on a new class of Σ-Δ modulation architectures.

Over the past thirty years all-digital frequency synthesis has attracted the interest of the scientific community because of the advantages of the digital circuits like design-automation, testability, robustness to noise, temperature, supply and process variations, etc. Downscaling of integration technologies makes all-digital frequency synthesis even more desirable as digital circuitry becomes faster and smaller in area while analog RF becomes more challenging to design and with limited area-scaling capability. All-digital frequency synthesizers [1] are finite state machines driven by a clock whose rising and falling edges specify those of the output. This implies that only integral division frequencies of the clock result in clean spectra, instead, all other generated frequencies result in spectra polluted with many and strong spurs. Techniques have been proposed to alleviate the spurs / timing jitter, most are summarized in [1], with random dithering being the only purely digital one.

Published work has demonstrated that dithering can eliminate all or selected spurs, however, it introduces a high noise-floor typically in the order of $10\log_{10}\left(f_{sampling}\right)$ dBc/Hz [2]. In contrast to previous work, this paper introduces all-digital frequency synthesis architectures with embedded new structures of band-pass sigma-delta modulators with frequency translation, generating the single-bit output via a digital non-linear feedback loop. This allows powerful noise shaping and spurs elimination in the pass-band of interest, yet, it raises many new challenges related to the selection of the noise transfer function, stability of the loop and realistic hardware implementation, all of which will be discussed in the presentation. A typical example of the output spectrum is shown in Fig. 1 where the pass-band is 2% of $f_{Nyquist} = f_{sampling}/2$ and the indicated DR is 140dB with RBW=333Hz. There is an inherent trade-off between the pass-band and DR which will also be discussed.

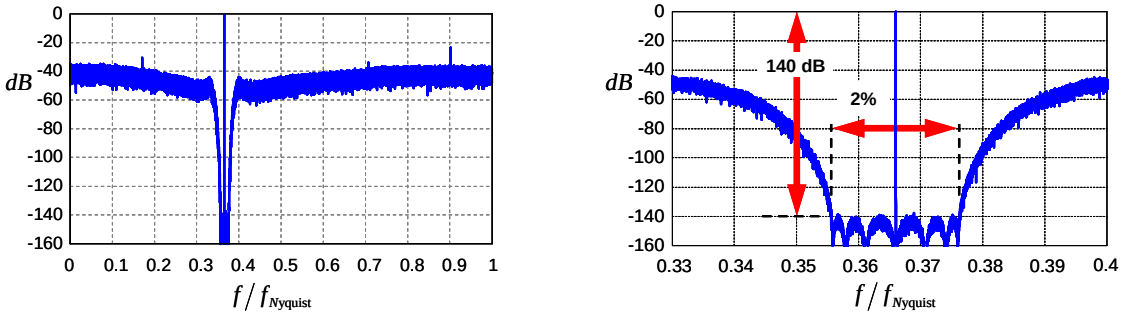

Fig. 1: Typical spectrum of the new all-digital frequency synthesizers based on Σ-Δ modulation. Spectrum (left) and zoom-in (right). Spectrum parameters: Resolution BW = 333Hz, $f_{Nyquist} = f_{sampling}/2 = 500\text{MHz}$, Clean 2% BW is 10MHz.

[1] P. Sotiriadis, K. Galanopoulos, "Direct All-Digital Frequency Synthesis Techniques, Spurs Suppression, and Deterministic Jitter Correction", IEEE Trans. on Circuits and Systems-I, Vol. 59, No. 5, May 2012, pp. 958-968.

[2] P. Sotiriadis, "All Digital Frequency Synthesis Based on Pulse Direct Digital Synthesizer with Spurs Free Output and Improved Noise Floor", IEEE Int. Frequency Control Symposium. 2014.