A Highly Digital Millimeter-Wave CMOS Frequency Synthesizer

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Frequency synthesizers that can tune over extremely wide bandwidths in finely spaced steps are essential components necessary to fully exploit the large spectrum swaths available in the millimeter-wave bands that are attractive for extreme data rate communications, ranging and imaging applications. The performance of conventional analog PLL, commonly used in RF frequency synthesizers, is degraded by the nonlinearities in the PFD and charge pump (CP) circuits, especially in low-voltage nanoscale CMOS technology. An all-digital PLL (ADPLL) employs a time-to-digital converter (TDC) and a digital loop filter to replace the analog PFD-CP-LPF blocks. This allows a high degree of programmability or reconfigurability to accommodate widely varying PVT and loop gain conditions. The main challenge in an ADPLL is the design of high-resolution, high-linearity TDC, which dictates the purity of the output spectrum of the PLL.

This research proposes a wideband mm-wave frequency synthesizer based on an ADPLL with fine frequency resolution, Fig. 1, to cover the 60GHz ISM band which extends from 57-66GHz. It consists of a wideband transformer-coupled DCO and a divide-by-4 prescaler operating at mm-wave. A phase-to-digital conversion is performed with a synchronous counter and a novel coarse-fine TDC. The fine TDC which is based on a Vernier delay line can provide less than 1ps resolution. However in order to overcome the nonlinearities introduced by PVT and mismatch, a calibration method based on statistical element selection has been employed. The rest of PLL consists of digital blocks for PFD and digital loop filter which can be easily programmed and digital signal processing can be readily applied to enhance the performance. For example, a gear shifting method in the loop filter is implemented to provide fast settling time. Digital blocks operating at clock frequency (200MHz) are synthesized using Verilog RTL.

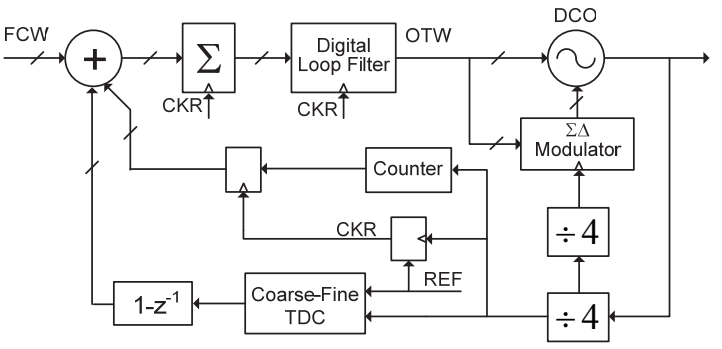

Figure 1: Block diagram of the proposed highly-digital mm-wave PLL