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Evaluating Direct RF Sampling Performance for RFSoC-based Radio-frequency Astronomy Receivers

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RF system-on-chip (RFSoC) devices have been widely used to develop receivers for radio astronomy applications since it has been released by Xilinx. Some of the applications, such as C-band surveys receivers [1], the readout for superconducting detectors of microwave SQUID multiplexers (μmux) or microwave kinetic inductance detectors (MKIDs) for Cosmic Microwave Background (CMB) experiments [3] and millimetre-wavelength telescope after first stage down-conversion [2], are operating in the frequency range of 4-8 GHz, which falls in the higher order Nyquist zones of the integrated data converters in RFSoC. Therefore, those receivers requires analogue down-conversion circuits to mix the frequency down to the first Nyqusit zone of the data converters. Due to the high demand direct RF sampling in telecommunication industry, Xilinx has advanced both the sampling speed and the RF input frequency of the analogue-to-digital converter (ADC) integrated in RFSoC devices. From GEN 1 RFSoC devices to the latest DFE RFSoC devices, the maximum sampling frequency of the ADCs has been increased from 4.096 GHz to 5.9 GHz and the maximum RF input frequency has been extended from 4GHz to 7.125 GHz [4]. Those improvements enable us to totally or partially eliminate the analogue down-conversion circuits, which can significantly simplify the architecture of the receiver systems and reduce the hardware cost of the systems, especially for systems with large channel counts.

The RF signals in higher order Nyquist zone are folded back to the first Nyquist zone, so the RF signal in higher order Nyquist zone can be sampled without down-mixing. Digital-up-coversion (DUC) and digital-down-conversion (DDC) are also included as a part of hardened radio frequency system in RFSoC. The integrated NCOs in DDCs and DUCs can be used to up or down convert the RF signal to desired centre frequency. Therefore, the combination of those components in the hardened radio system in RFSoC can replace the analogue mixing required for some of the applications. In this paper, we present the wide-band performance evaluation results for direct RF sampling schemes with RF data converters and other parts of hardened radio system with different generations of RFSoC devices. The performance of the integrated data converters sampling at first Nyquist zone has been comprehensively discussed in [1]. The focus of this paper is the performance characterization of direct RF sampling at higher orders of Nyquist zones and the integrated DUCs and DDCs. The results can be used as a guide line for future system design and development for RFSoC-based radio-frequency receiver or readout systems with minimum analogue mixing circuits.

References

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