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High-Bandwidth Signal Reception with Improved ENOB by Photonics Sampling

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The demand for higher data rate and better coverage for wireless systems is driven by the exponential growth of data traffic. Thus, 6G and beyond wireless systems aim to support 1 Tbps peak data rates [1]. Such high data rates require higher carrier frequencies in the THz region of the electromagnetic spectrum (0.3 – 3THz). However, at the same time, higher baseband widths are needed to reduce the demands on spectral efficiencies. One bottleneck for the processing of higher baseband bandwidths is the electronic analog to digital conversion (ADC) of the received signal. Electronic ADCs appear to be struggling to keep pace with the exponentially increasing data rates [2], [3]. According to the Walden plot and assuming 100 fs Jitter, electronic ADCs can only reach an effective number of bits (ENOB) of around 4 for an analog input frequency of 62.5 GHz, for instance [2], [4]. Thus, effectively only 16 amplitude values are available for the coding of the signal. This increases the requirements for the following signal processing and drastically reduces the spectral efficiency for the transmission.

Here we will present a system, which enables the analog to digital conversion of high-bandwidth signals with improved ENOB. Each bandwidth limited signal B (baseband $B/2$) can be seen as a superposition of time-shifted sinc-pulses weighted with the data points. Thus, the high-bandwidth input signal with a bandwidth B is divided into N sub-branches by optical sampling of the input signal with sinc-shaped Nyquist pulses that are generated using optical flat line combs [4]–[6]. This requires only a properly biased Mach-Zehnder modulator and a radio frequency oscillator. Since this optical sampling does not add any error to the signals in the sub-channels, they can be detected in parallel with a baseband bandwidth of $B/(2N)$. Therefore, the high bandwidth signal can be detected and processed with low baseband bandwidth electronics of $B/(2N)$, which will be proven by our theory and results. This leads to a noticeable performance enhancement as low bandwidth electronics tend to provide a better ENOB [1].

For meteorology application, the best in-class components were considered for the simulation (e.g. input laser with a relative intensity noise (RIN) of -160 dB/Hz [7]). Thus, for $N = 9$ branches (9-line comb of 126 GHz bandwidth) for instance, electronic ADCs with a bandwidth of 7 GHz are sufficient to sample a signal with a baseband width up to 62.5 GHz with an ENOB of 6.54. Thus, due to the bandwidth reduction of the required electronics, an ENOB improvement of 2.54 was achieved (from 4 to 6.54), which corresponds to a ~17 dB signal-to-noise and distortion (SINAD) enhancement.

[1] I. F. Akyildiz, C. Han, Z. Hu, S. Nie, and J. M. Jornet, "TeraHertz Band Communication: An Old Problem Revisited and Research Directions for the Next Decade," no. Dl, 2021, [Online]. Available: http://arxiv.org/abs/2112.13187.

[2] A. Khilo *et al.*, "Photonic ADC: overcoming the bottleneck of electronic jitter," *Opt. Express*, vol. 20, no. 4, p. 4454, 2012, doi: 10.1364/oe.20.004454.

[3] T. Cisco and A. Internet, "Cisco: 2020 CISO Benchmark Report," *Comput. Fraud Secur.*, vol. 2020, no. 3, pp. 4–4, 2020, doi: 10.1016/s1361-3723(20)30026-9.

[4] A. Misra, C. Kress, K. Singh, S. Preußler, J. Christoph Scheytt, and T. Schneider, "Integrated source-free all optical sampling with a sampling rate of up to three times the RF bandwidth of silicon photonic MZM," *Opt. Express*, vol. 27, no. 21, p. 29972, 2019, doi: 10.1364/oe.27.029972.

[5] J. Meier, A. Misra, S. Preußler, and T. Schneider, "Orthogonal Full-Field Optical Sampling," *IEEE Photonics J.*, vol. 11, no. 2, 2019, doi: 10.1109/JPHOT.2019.2902726.

[6] S. Preußler, G. Raoof Mehrpoor, and T. Schneider, "Frequency-time coherence for all-optical sampling without optical pulse source," *Sci. Rep.*, vol. 6, pp. 1–10, 2016, doi: 10.1038/srep34500.

[7] A. Kerchaoui *et al.*, "Electrically pumped shot-noise limited class A VECSEL at telecom wavelength," *Opt. Lett.*, vol. 46, no. 10, p. 2465, 2021, doi: 10.1364/ol.412746.