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A3 : Photonics-Assisted ADC with Bandwidth Reduction and Resolution Improvement

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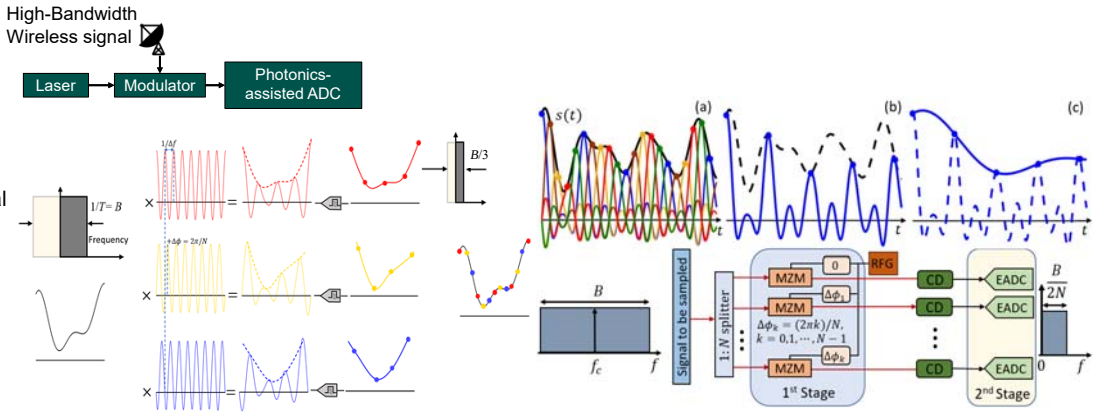
Abstract

- Sampling is the first step to convert analog to digital signals at the receiver.
- Photonics-assisted ADCs (PADCs) overcome bandwidth and resolution limits of electronic ADCs (EADCs).
- Optical sub-Nyquist orthogonal sampling uses sinc-pulse sequences to time-interleave high bandwidth signals into low-bandwidth sub-signals (first stage).
- Sub-signals are detected and processed in parallel by low-bandwidth electronics (second stage).
- Orthogonal sampling with ideal devices is error-free and avoids aperture jitter.
- Enables high ENOB and wideband reception with low-bandwidth components.

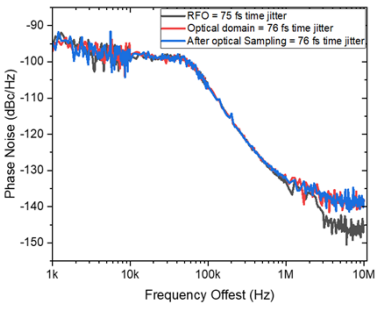
Concept

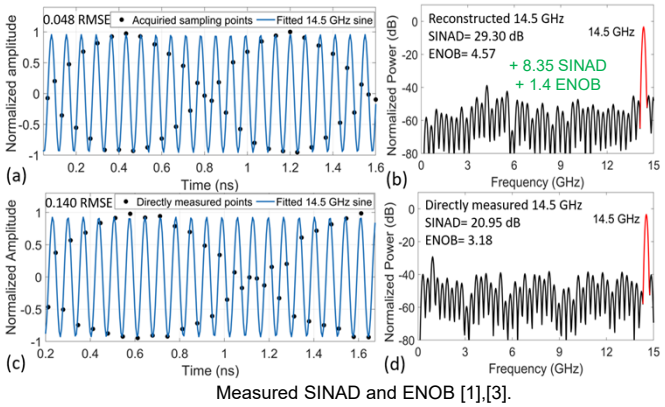
- The signal is first converted to the optical domain.
- It is split into *N* sub-branches.
- Each sub-branch samples the signal using a sinc-pulse sequence.
- The sequence is generated via an RF source and an intensity modulator (e.g., MZM or MRM).
- Sampled signals are detected and digitized with low-bandwidth electronics.
- This enables high ADC rates, improved SINAD, and higher ENOB.

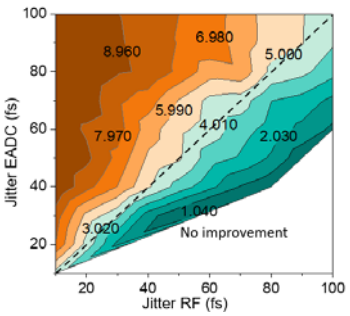


Photonics-assisted analog-to-digital converter [1].

Results







$$SINAD = 10Log_{10}\left(\frac{1}{(\pi f \sigma_{RF})^2 + \left(2\pi \frac{f}{N}\sigma_{ADC}\right)^2}\right)$$

$$ENOB = \frac{SINAD - 1.76}{6.02}$$

Measured SINAD and ENOB [1],[3].

Summary

- PADC provides higher processing signal bandwidth compared to pure EADC.
- Simple high-quality optical sampling with sinc-pulse sequences.
- Only a frequency oscillator is needed with an optical intensity modulator.
- Investigation of Jitter effect.
- No aperture jitter is added with PADC.
- Analysis of the achievable ENOB and SINAD.
- Higher ENOB than state of the art EADC.

	14.5 GHz Signal to be Sampled			62.5 GHz Signal to be Sampled
	Experiment	Simulation	Best-in-class Simulation	Best-in-class Simulation
Sampled with	EADC			EADC
SINAD, ENOB	20.95 dB, 3.18 bit	21.23 dB, 3.23 bit	39.68 dB, 6.3 bit	27.04 dB, 4.20 bit
Sampled with	PADC with three branches			PADC with nine branches
SINAD, ENOB	29.30 dB, 4.57 bit	30.01 dB, 4.69 bit	48.73 dB, 7.80 bit	43.41 dB, 6.92 bit
Improvement	1.4 bit	1.46 bit	1.5 bit	2.72 bit

References

[1] Y. Mandalawi, J. Meier, K. Singh, M. I. Hosni, S. De, and T. Schneider, "Analysis of Bandwidth Reduction and Resolution Improvement for Photonics-Assisted ADC," J. Light. Technol., vol. 41, no. 19, pp. 6225–6234, Oct. 2023, doi: 10.1109/JLT.2023.3279876.

[2] Y. Mandalawi, M. I. Hosni, J. Meier, L. Zhou, and T. Schneider, "Compact Optical Sampler for Broadband Wireless Signals," IEEE Access, vol. 12, no. December, pp. 184509–184516, 2024, doi: 10.1109/ACCESS.2024.3513482.

[3] Y. Mandalawi et al., "Photonics Assisted Analog-to-Digital Conversion of Wide-Bandwidth Signals by Orthogonal Sampling," in 2023 53rd European Microwave Conference, EuMC 2023, IEEE, Sep. 2023, pp. 464–467. doi: 10.23919/EuMC58039.2023.10290623.