Paper Number: 5642

A Hardware Prototype of Sub-Nyquist Modulo Sampling of FRI Signals

Satish Mulleti, Eliya Reznitskiy, Nimrod Glazer, Moshe Namer, and Yonina C. Eldar

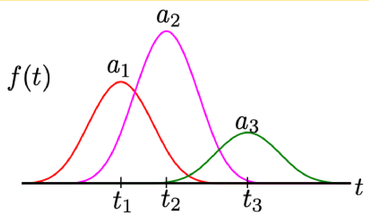
Faculty of Math and CS, Weizmann Institute of Science, Rehovot, Israel
Email: mulleti.satish@gmail.com

Motivation and Contributions

- Sampling and quantization are critical tasks of an ADC
- At high sampling rates ADCs are expensive and power consuming
- Large dynamic range of the input compared to that of the ADC results in clipping during quantization
- To address clipping, signal structure is used to sample at a sub-Nyquist rate and a modulo operation is applied on the signal to restrict the dynamic range
- In this demo, a hardware prototype is developed that performs sub-Nyquist sampling of finite-rate-of-innovation signals with a modulo operation

FRI Sampling and Reconstruction

- Stream of known pulses: $f(t) = \sum_{\ell=1}^{L} a_\ell \overset{\text{Known}}{\overbrace{h}}(t - t_\ell)$



- Signal $f(t)$ is parametrized by amplitudes and time-delays
- $2L$ Fourier samples of $f(t)$ uniquely determine the parameters
- Sub-Nyquist sampling scheme enables computation of the Fourier samples from low rate samples

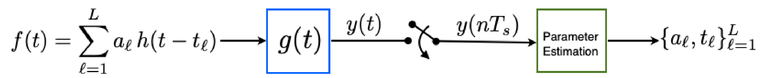


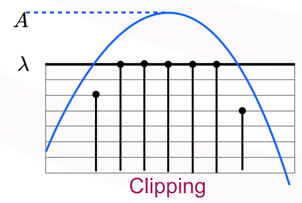
Fig: Sampling and reconstruction of FRI signal by using a sampling kernel $g(t)$

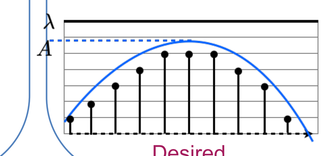
Dynamic Range of ADC

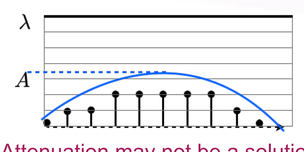
- The ratio of the dynamic ranges of the input and the ADC is crucial in signal representation

A: max amplitude of input

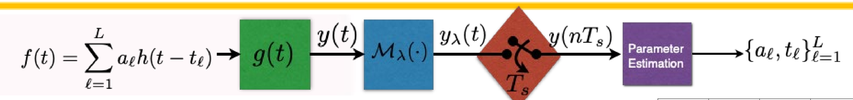
λ: dynamic range of ADC



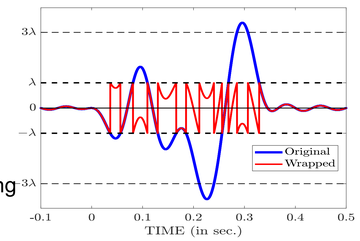




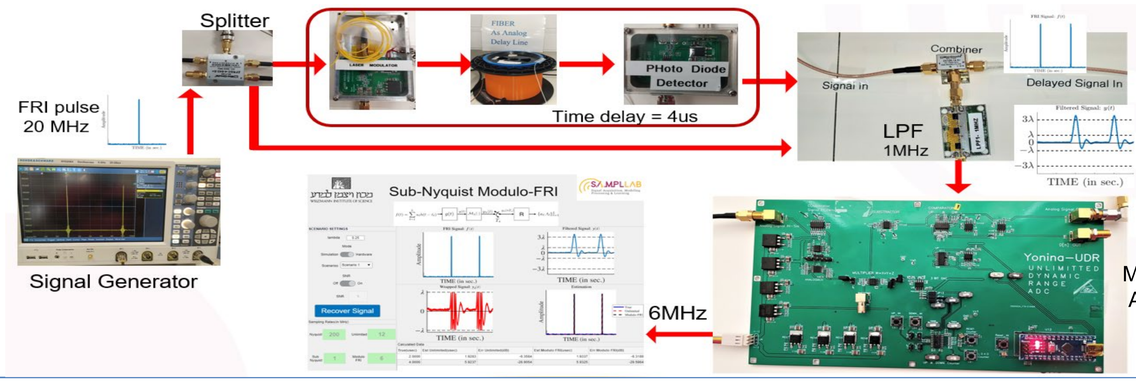
Modulo Sampling



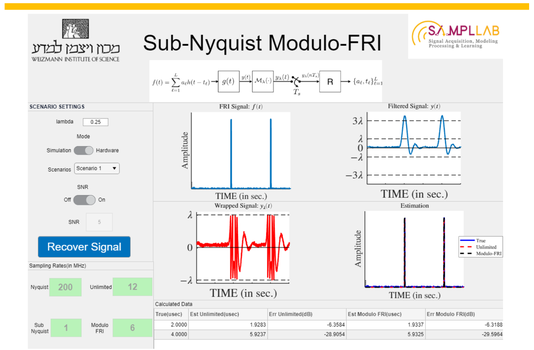
- To address clipping, unlimited sampling approach is proposed by Bhandari et al. IEEE TSP 2020
- The approach uses a modulo operation to limit the dynamic range
- It operates at 8.5 times the sub-Nyquist rate
- We propose an alternative modulo-FRI approach for recovery that requires sampling at twice the sub-Nyquist rate in the absence of noise
- We build a hardware prototype to demonstrate sub-Nyquist sampling of FRI signals in the presence of modulo operation



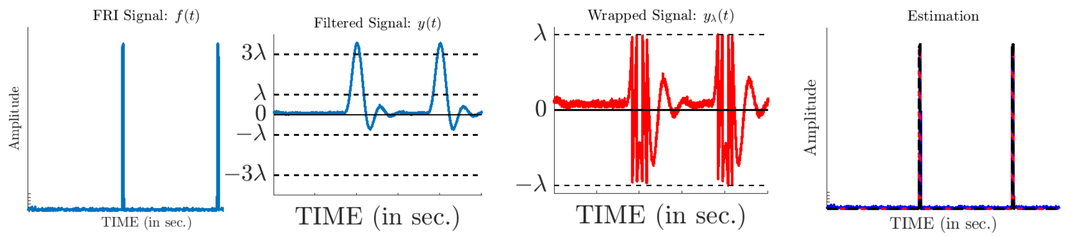
Hardware



User Interface



Results



Sampling rates: Nyquist 20MHz, sub-Nyquist (no modulo): 1MHz
Unlimited: 12MHz; Proposed modulo FRI: 6MHz

- We consider an FRI signal f(t) consisting of 2 pulses of bandwidth 20MHz and delay between them is 4μs
- The signal is lowpass filtered with a cutoff frequency 0.5MHz
- The filtered signal is passed through a modulo operator to restrict the dynamic range
- The modulo signal is sampled at 12MHz and 6MHz
- Unlimited sampling recovery is used with 12MHz samples and then delays are estimated
- The proposed modulo-FRI method is used to reconstruct from 4MHz samples
- Both approaches estimate the time-delays with MSE -10 dB whereas the proposed approach operates at 2 times less sampling rate
- Our modulo hardware addresses the dynamic range issue of the input signal and leads to perfect recovery