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: \( f(t) = \sum_{E=1}^{\infty} a_E h(t - t_E) \)
- 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.

Dynamic Range of ADC

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

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

- FRI pulse 20 MHz
- Time delay = 4us
- 1MHz LPF
- Sub-Nyquist Module-FRI
- 6MHz modulo ADC
- Signal Generator

Results

- We consider an FRI signal \( f(t) \) consisting of 2 pulses of bandwidth 20MHz and delay between them is 4us.
- 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.

User Interface

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