Revolution frequency invariant reconstruction of bunch profiles in fixed frequency clock systems

D. Barrientos, J. Molendijk, B. Bielawski
CERN, Geneva, Switzerland

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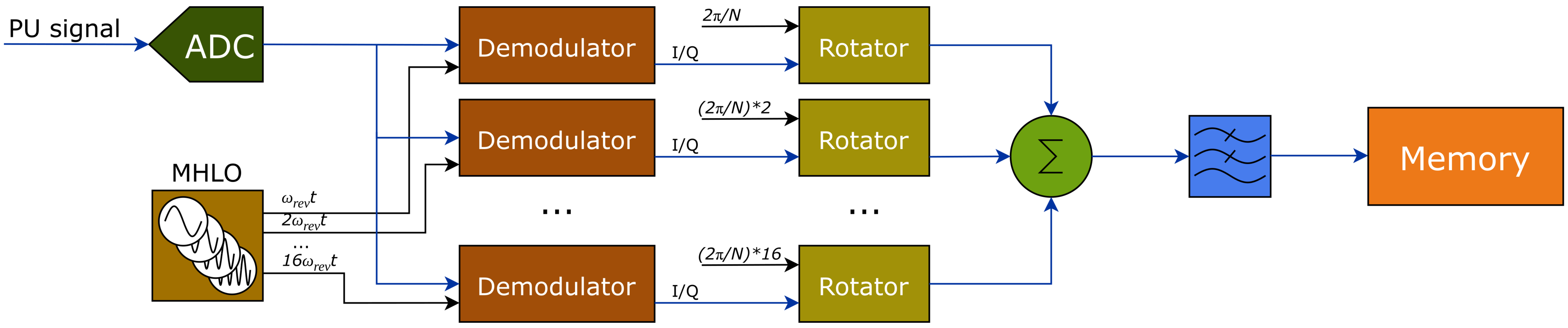
Principle

During the last few years, the LLRF systems of all CERN small synchrotrons (PSB, LEIR, AD, ELENA) have been upgraded to a fixed frequency clock scheme [1]. As a result, the beam profiles obtained from the digitization of pick-up signals will have a different number of samples as the revolution frequency varies. In this work, we present a method to reconstruct the time-domain signal of the bunch profile by using the demodulated values of 16 harmonics of the revolution frequency. This method uses a digital Multi Harmonic Local Oscillator (MHLO) efficiently using the FPGA resources and individual demodulators with out-of-band filtering. The constant number of samples for the bunch profiles allows a better visualization of the evolution of the bunch shapes during the cycle.



Building blocks

Fixed frequency clock

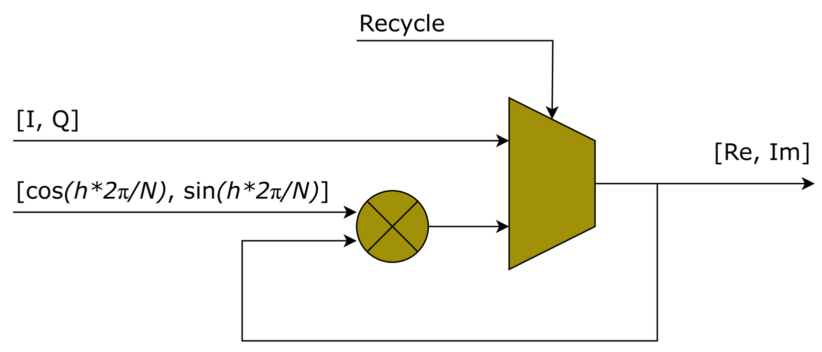
The chosen frequency is for VXS systems is about 122.7 MHz [1]. This allows the ADCs to be operated at their optimal frequency, avoiding complex DDS schemes and having harmonic distortion out of band.

Multi-harmonic source

This block produces 16 sine and cosine waveforms at harmonics of the revolution frequency [2]. These signals are used to demodulate individually 16 harmonics of the revolution frequency.

Demodulators

The 16 individual demodulators have been designed to minimize resource usage and to operate with a fixed frequency clock [1]. The current architecture is also used in the PSB multi-harmonic cavity controller [3].



Rotators

Demodulated data (I, Q) of each harmonic are modulated (rotated) with a fixed phase increment. Each rotator is incremented by an angle such that a complete turn is achieved using the same number of samples.

In order to optimize the resource usage, the vector rotation is pre-computed and applied several times to the same I, Q pair.

Two dimensional low-pass filter

This filter computes an average of frames (bunches) composed by a fixed number of samples. Its input is the sum of all real components of the 16 harmonics.

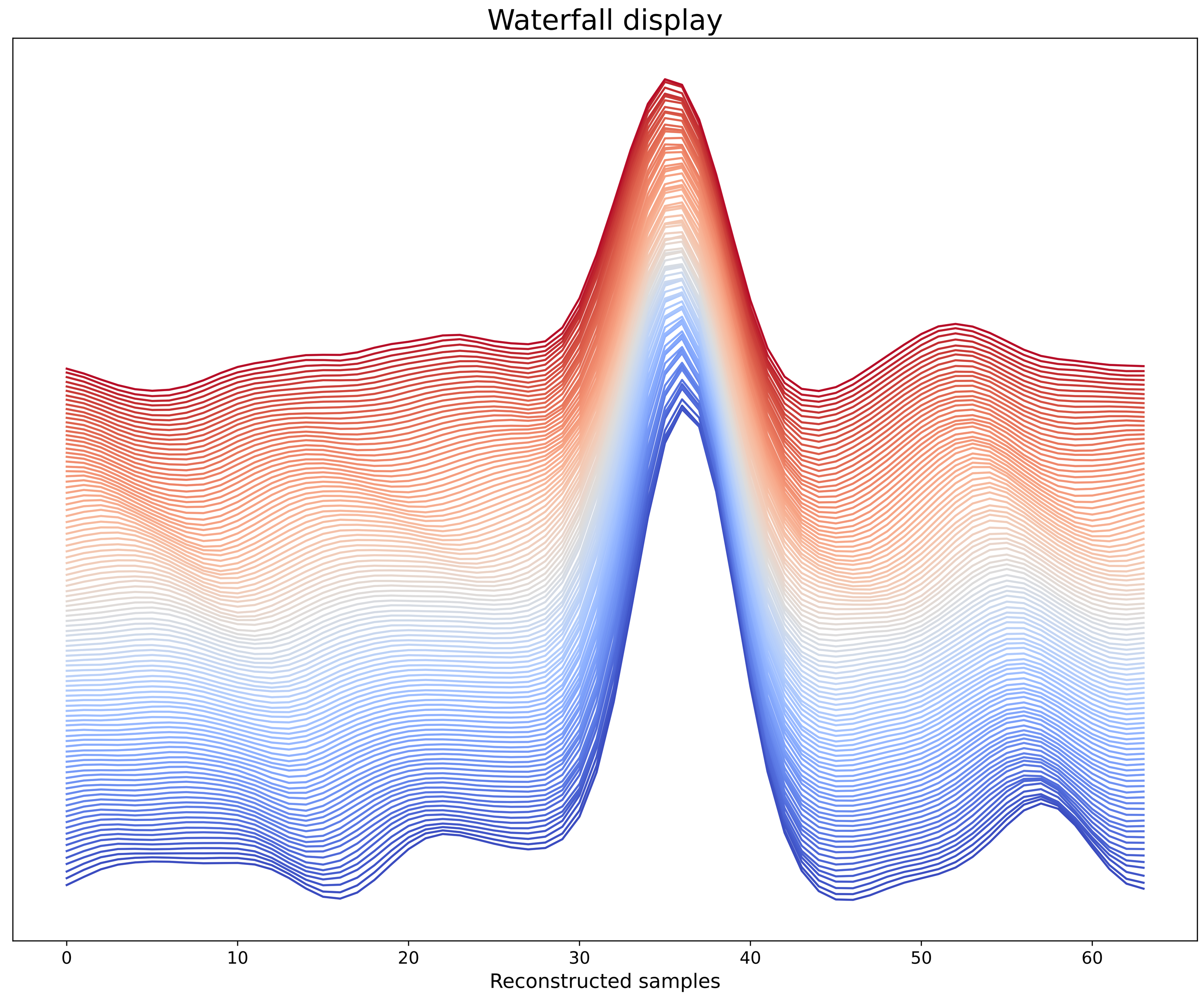
Acquisition

The acquisition to memory is controlled by specific timings, which are automatically set to operate only when the beam is bunched. This allows saving only relevant data in the memory. The implementation includes a dual buffer memory to be able to continue recording data while reading the contents of the previously recorded events.

Results

The frequency components of a pick-up signal are mainly products of revolution frequency harmonics. Thus, by adding together the contributions of the first 16 revolution frequency harmonics, the time-domain signal can be reconstructed.

The advantage of this system is that the reconstructed signal will be independent of revolution frequency changes during acceleration (or deceleration) ramps, as if the data would have been sampled with a sweeping frequency clock.



In the figure, an acquisition of a Longitudinal Pick-Up (LPU) signal in ELENA is shown. The revolution frequency is changing between about 900 to 750 kHz. The plot displays 100 reconstructed samples.

This system is currently being tested in AD and ELENA machines, together with the new longitudinal diagnostics system [4].

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REFERENCES

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