Optimization of Parallel Processing Intensive Digital Front-End for IEEE 802.11ac Receiver

Juha YLI-KAAKINEN, Toni LEVANEN, Mona AGHABABAEETAFRESHI, Markku RENFORS, and Mikko VALKAMA

Abstract

In this study we investigate the parallel processing of the IEEE 802.11ac waveform. Two multirate architectures are developed with the corresponding parameter optimization. The performance of the architectures is verified through simulations.

In IEEE 802.11ac WLAN/WiFi technology, the 80 MHz access waveform is essentially composed by aggregating two 40 MHz sub-signals, stemming from the legacy IEEE 802.11n access bandwidth.

This 80 MHz signal can be divided to two 40 MHz sub-signals, through optimized time-domain filtering, which in turn can then be processed forward in parallel, with two smaller-size FFTs and corresponding frequency-domain processing.

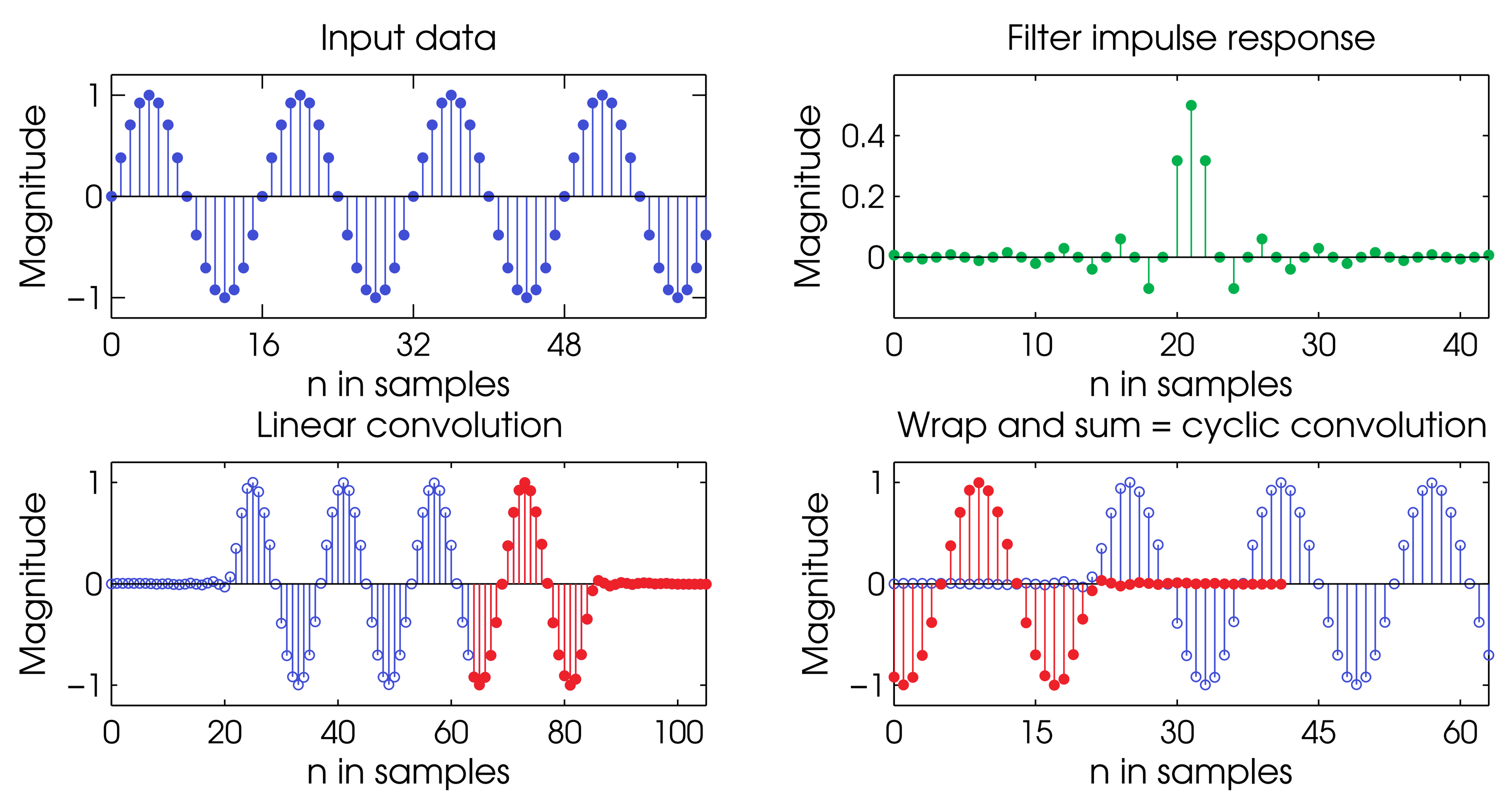
The channelization filter design task is formulated as an optimization problem and two alternative channelization architectures are provided with different characteristics and tradeoffs related to latency, filtering performance, and cyclic prefix (CP) budget.

Channelization Problem

The channelization problem stated above can be solved using conventional linear filters before the removal of the CP. The inclusion of the CP effectively converts the linear convolution between the received multicarrier symbols and the channelization filters into the cyclic convolution and thus the passband frequency responses of the channelization filters can be equalized at the subcarrier level after the FFT.

However, the linear filter based channelization increases the effective time dispersion of the received signal and, therefore, the filter length and, consequently, the filter performance is limited by the available CP budget.

Alternatively, the channelization can be performed using cyclic filters after the removal of CP without compromising the CP budget.



Channelization Filter Optimization

The optimization goal is to minimize the maximum of the root-mean-squared error between the received and transmitted burst of symbols as expressed as

$$\mathbf{e} = \max \mathrm{norm}\, \|\mathbf{Y} - \mathbf{X}\|_2.$$

When the frequency responses of the channelization filters have very small magnitude on their passband regions, the equalizer will amplify the noise on the corresponding subcarriers. Therefore, an additional constraint is needed for constraining the passband ripple of the equalizers:

$$\mathbf{c} = \big\| \left[\mathbf{h}_N \quad \mathbf{h}_P\right] \big| - 1\big| - \Delta_p.$$

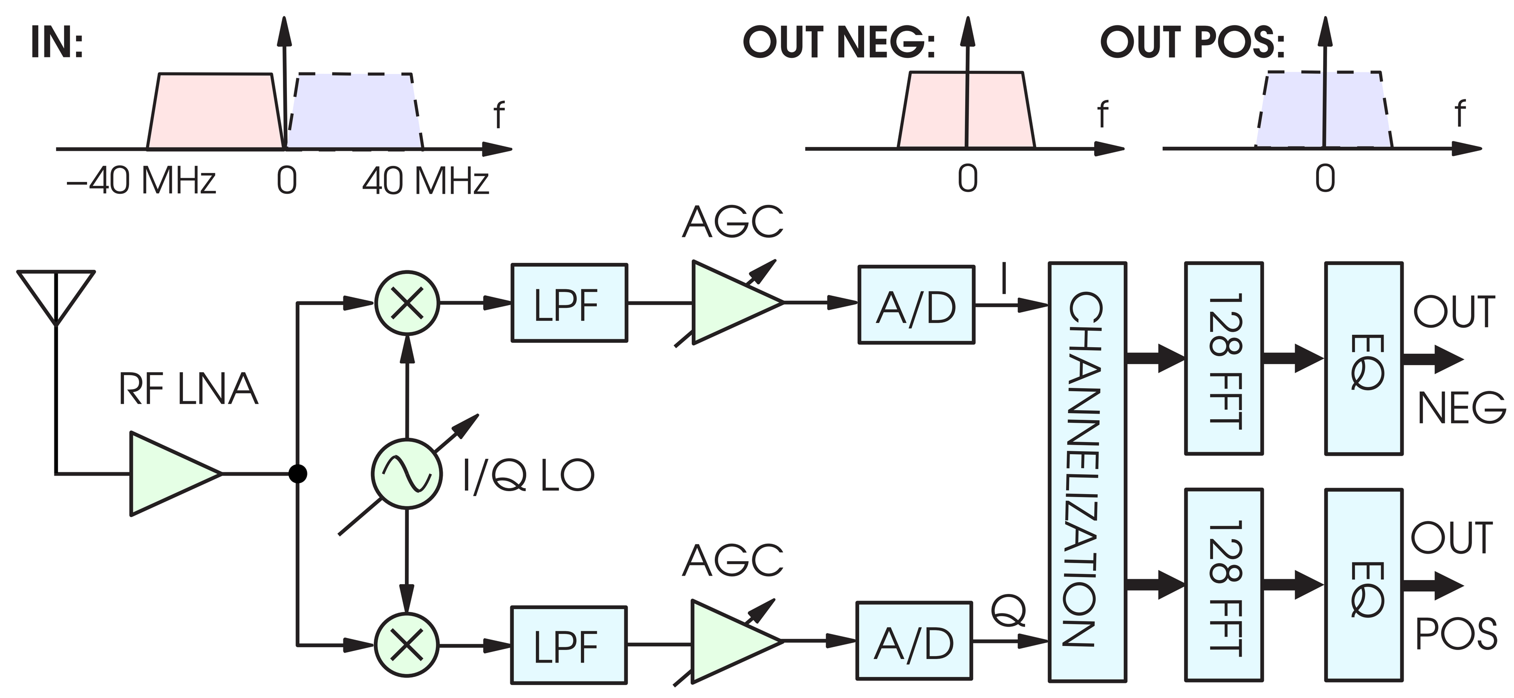
Here, Δ_p is the desired maximum passband ripple of the equalizers.

Optimization problem: Find the parameters of the channelization filters such that $\mathbf{e}$ is minimized subject to the constraint that $\mathbf{c} \le 0$.

Example: 80 MHz access bandwidth in IEEE 802.11ac system

- 256 subcarriers, out of which 242 are active (both the negative and positive frequency components contain 121 transmission subcarriers.)
- The total multicarrier symbol duration is defined as 4 μs; 20 percent of this duration (800 ns) is the guard interval which carries the CP of the signal.
- The number of OFDM symbols is 100, the number of channel instances is 1000.
- Channel Model F with moderate-to-large frequency selectivity (large indoor spaces) [IEEE Standard 802.11-03/940r4].

The symbol error rate (SER) has been evaluated in the following cases. 1) the performance is evaluated using conventional linear halfband filter where the channelization is carried out before the CP removal. 2) the channelization is performed after the CP removal either using cyclic halfband filter or cyclic non-halfband filters. 3) the performance in the case with no channelization.



Channelization Filter Optimization

In order to optimize the performance of the cyclic filter based channelization architecture, the overall synthesis-analysis filter bank system is decomposed as

$$\mathbf{Y} = \begin{bmatrix}\mathbf{Y}_P\\ \mathbf{Y}_N\end{bmatrix} = \begin{bmatrix}\mathbf{H}_P\\ \mathbf{H}_N\end{bmatrix}\mathbf{F}_L^{-1}\mathbf{X}.$$

Here, $\mathbf{X}$ is the matrix containing the input symbols on the positive and the negative subcarriers, whereas the L-by-L inverse DFT matrix $\mathbf{F}_L^{-1}$ represents the synthesis filter bank with L subcarriers. The analysis filter pair can be expressed as

$$\mathbf{H}_P = \mathrm{diag}(\mathbf{h}_P)\mathbf{F}_{L/2}\mathbf{D}\mathbf{C}_P \quad \text{and} \quad \mathbf{H}_N = \mathrm{diag}(\mathbf{h}_N)\mathbf{F}_{L/2}\mathbf{D}\mathbf{C}_N,$$

where $\mathbf{C}_P$ and $\mathbf{C}_N$ are the cyclic convolution matrices of the analysis filter pair used for separating the positive and negative subcarriers, respectively. $\mathbf{D}$ is downsampling by two matrix and $\mathbf{F}_{L/2}$ is a $L/2$-by-$L/2$ DFT matrix.