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## Chapter XVIII

# Design of Narrowband Highpass FIR Filters Using Sharpening RRS Filter and IFIR Structure

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## ABSTRACT

*This chapter presents the design of narrowband highpass linear-phase finite impulse response (FIR) filters using the sharpening recursive running sum (RRS) filter and the interpolated finite impulse response (IFIR) structure. The novelty of this technique is based on the use of sharpening RRS filter as an image suppressor in the IFIR structure. In that way, the total number of multiplications per output sample is considerably reduced.*

## INTRODUCTION

FIR filters are often preferred to infinite impulse response (IIR) filters because of their attractive properties, such as the linear phase, stability and the absence of the limit cycle (Mitra, 2001). The main disadvantage of FIR filters is that they involve a higher degree of computational complexity compared to IIR filters with equivalent magnitude response. In the past few years, many design methods have been proposed to reduce the complexity of FIR filters, (Jou, Hsieh & Kou, 1997; Kumar & Kumar, 1999; Webb & Munson, 1996; Lian & Lim, 1998; Bartolo & Clymer, 1996, etc.).

We consider highpass (HP) linear-phase narrowband filters. As it is known, one of the most difficult problems in digital filtering is the implementation of narrowband filters. The difficulty lies in the fact that such filters require high-order design in order to meet the desired frequency response specifications. In return, these high-order filters need a large amount of computation and are difficult to implement. Here we propose an efficient implementation of HP liner-phase narrowband digital filters based on IFIR and RRS filter.

We first consider the transform of a lowpass filter (LP) into its HP equivalent. We then describe the design of HP filters using an IFIR structure, separately considering an even and an odd interpolation factor. We also review the basics of RRS and sharpening RRS filters. Finally, we explain how to design an HP filter, using the sharpening RRS-IFIR structure. Two methods are presented, but the choice between the two depends on the parity of the RRS filter. Several examples accompany the outlined procedures. All filters are designed using MATLAB.

# TRANSFORM OF LP INTO HP FILTER

Instead of designing an HP filter by brute force, we can transform an LP filter into an HP one. First we replace the desired cutoff frequencies of the HP filter, $\omega_p$ and $\omega_s$, with the corresponding LP specifications as follows:

$$\begin{aligned} \omega_p' &= \pi - \omega_p \\ \omega_s' &= \pi - \omega_s \end{aligned} \tag{1}$$

Given these specifications, an LP-FIR filter can be designed. From this auxiliary LP filter, the desired HP filter can be computed by simply changing the sign of every other impulse response coefficient. This is compactly described in Equation 2:

$$h_{HP}(n) = (-1)^n h_{LP}(n) \tag{2}$$

where $h_{HP}(n)$ and $h_{LP}(n)$ are the impulse responses of the HP and the LP filters, respectively.

The following example illustrates the procedure.

**Example 1:** We consider the design of HP-FIR filter using Parks-McClellan algorithm (Mitra, 2001) with these specifications: normalized passband edge $\omega_p$ =

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