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A Method For Narrowband HP FIR Filter Design Using Fewer Multiplications

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ABSTRACT

This paper presents a new efficient method for the design of narrowband highpass filters (HP) with fewer multiplications. The method is based on an Interpolated filter (IFIR) structure and the sharpened comb filter (SCF). The novelty of the technique is based on the usage of the SCF filter as an image suppressor in the IFIR structure. The method is useful for narrowband HP filter design.

INTRODUCTION

Finite impulse response (FIR) filters are known to have some very desirable properties such as linear phase, stability, and absence of limit cycle, however their application generally requires more computation. A number of techniques have been proposed to reduce the complexity of FIR filters over the past years. This method belongs to the group of methods which separate the filter transfer function into two or more components having much lower order than the prototype filter (T.Saramaki at al., 1988; Jovanovic-Dolecek and Reyes, 1999; Lian and Lim, 1998 , etc).

We consider 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 designs in order to meet the desired frequency response specification. In turn, high order filters require a large amount of computation and so are difficult to implement. In this paper we propose an implementation of a narrowband high-pass filter using Interpolated FIR (IFIR) filters (T. Saramaki at al., 1988) and sharpened comb filter, (Kwentus at al., 1997).

The basic idea behind IFIR filters is to implement a FIR filter as cascade of two FIR filters, $G(z^L)$ and $I(z)$, such that each filter in the cascade has a much lower order than the prototype filter $H(z)$.

The filter $G(z)$, named the shaping filter is a linear-phase lowpass filter . The unwanted images introduced in going from $G(z)$ to $G(z^L)$ are suppressed by the interpolation filter $I(z)$.

In (Jovanovic-Dolecek and Reyes 1999) is proposed to use a comb filter as an interpolation filter. A comb filter has a very narrow passband, wide transition band and large side lobes.

In order to improve the characteristics of the comb filter, in this paper we propose the structure described in the following section.

PROPOSED STRUCTURE

Kwentus at al., 1997, proposed a sharpened comb filter for the multirate applications

$$H_{sh}(z) = 3H_c^2(z) - 2H_c^3(z), \tag{1}$$

where the comb filter Hc(z) is given as

$$H_c(z) = \left(\frac{1}{L}\frac{1-z^{-L}}{1-z^{-1}}\right)^K = \left(\frac{1}{L}\sum_{n=0}^{L-1} z^{-n}\right)^K, \tag{2}$$

and K is called a stage. As it is seen in equation (2), all coefficients are equal to 1 so it is not necessary to apply any multiplication.

The described structure may be used for the design of a lowpass filter.

In order to design a highpass filter, we replace the cutoff frequencies of the highpass filter, ω_p and ω_s, by the corresponding lowpass specifications as follows,

$$\omega_p' = \pi - \omega_p \qquad \omega_s' = \pi - \omega_s \tag{3}$$

Given the specification (3), a lowpass IFIR sharpened filter can be designed.

For an even interpolation factor L, the unwanted spectrum is at low frequencies and the desired spectrum is at high frequencies. So in order to eliminate the unwanted spectrum, it is only necessary to derive a highpass interpolation filter from its lowpass counterpart. This is done by changing the sign of every other coefficient

$$h_{HP}(n) = (-1)^n h_{LP}(n) \tag{4}$$

Therefore, for an even L, we transform the sharpened filter into a highpass filter using (4).

For an odd interpolation factor L it is necessary transform both the shaping filter G(z) and the sharpened filter $H_{sh}(z)$ into highpass filters.

The method is illustrated in the next example:

Example 1:

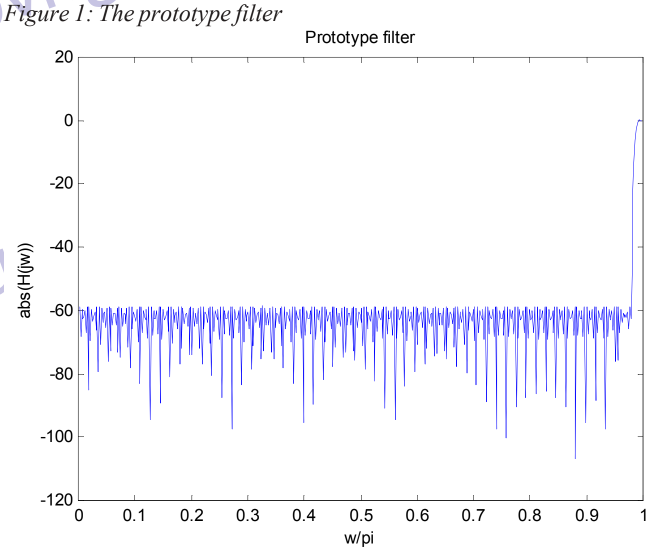
We design the highpass filter with the passband frequency w_p=.991 and the stopband frequency w_s=.98. Passband ripple is .2 db and the stopband attenuation 60 db.

The prototype HP linear phase filter has an order of N=458 and is shown in Figure 1.

We use L=16 and K=2 in the proposed structure and obtaining a shaping filter whose order is NG=33. The result is shown in Figure 2.

Figure 2 confirms that the passband specification is satisfied.

Figure 1: The prototype filter



Figuer 2: The designed filter

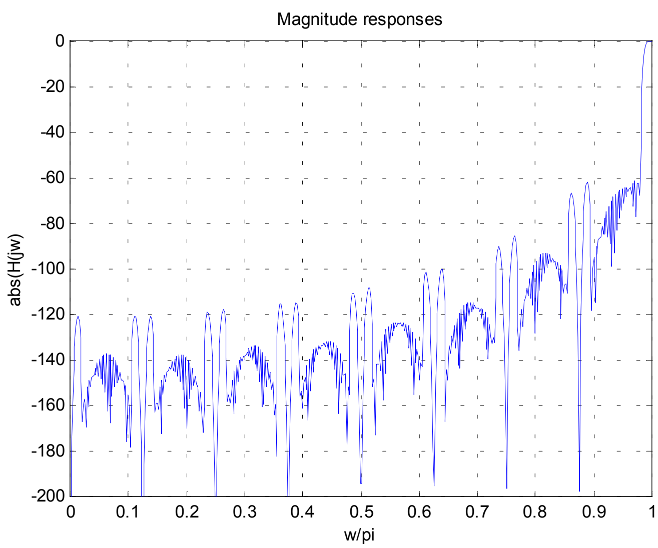
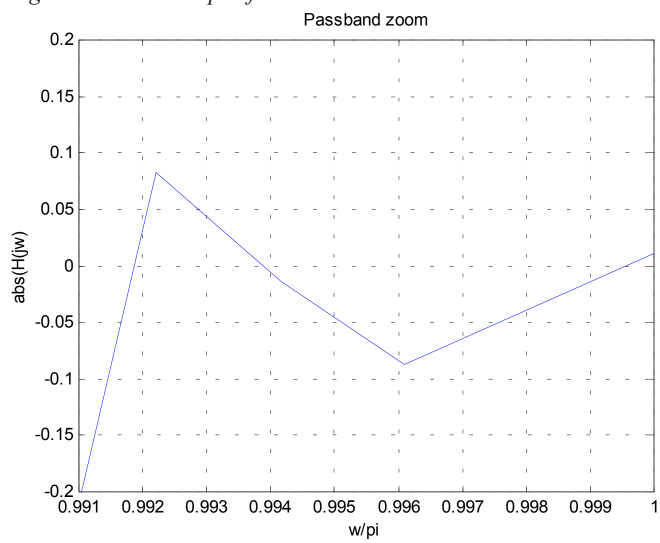


Figure 3: Passband specification



CONCLUSION

This paper presents one method for the narrowband highpass filter design with the aim to decrease the number of the multiplications. The method is based on the application of an IFIR structure where the interpolation filter is a sharpened comb filter.

The sharpened comb filter has an advantage because no multipliers and no storage are required for the interpolator coefficients. The overall result is the lower computational complexity of the resulting IFIR structure. The method is especially useful in the design of very narrowband high pass FIR filters and its efficiency increases with the increase of the interpolation factor L.

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