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NOVEL SHARPENED COMPENSATED COMB DECIMATOR

Gordana Jovanovic Dolecek
Institute INAOE
Enrique Erro 1, Tonantzintla, 72840 Puebla
Mexico

Vlatko Dolecek
Faculty of Mechanical Engineering
Vilsonovo setaliste, bb., 71000 Sarajevo
Bosna & Herzegovina

ABSTRACT

This paper presents the novel comb decimator. The method is based on the pass band comb compensation and the sharpening technique. The compensator is the simple multiplier less filter which can be moved to a lower rate which is M times less than the high input rate where M is the decimation factor. The parameters of compensator are independent of the decimation factor. The resulting filter is the multiplier less filter and exhibits the significantly decreased pass band droop, as well as the increased attenuation in the folding bands, compared with the corresponding comb filter.

Keywords: decimation, comb, compensation, sharpening.

1. INTRODUCTION

There is a continuous trend to replace analog circuitry to digital. Advanced developments in Analogue to Digital (A/D) and Digital to Analogue (D/A) conversion techniques, based on delta sigma modulation are best example of the design trend of shifting more and more signal processing tasks from the analog to the digital domain. This approach avoid strong requirements for the analog anti-aliasing filter, resulting in a simpler analog filter design while requiring fast more complex digital structure. The oversampled rate must be decreased in the digital form. The process of decreasing sampling rate is called decimation and consists of two stages: filtering and down sampling by an integer, as shown in Fig.1.

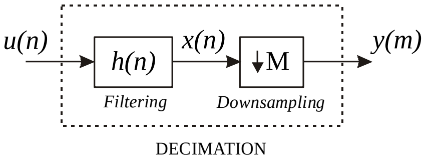

Figure 1. Decimation.

Down sampling reduces the input sampling rate by an integer factor *M*, which is known as a down sampling factor. The filter is necessary to avoid aliasing (overlapping of spectra introduced during the down sampling). Otherwise the overlapping effect should change the signal irreversibly. Consequently the design of decimation systems is mainly a filter design problem where is a great need to get a low complex filter but keeping performance of the filter in acceptable ranges [1].

The most simple decimation filter is the comb filter proposed by Hogenauer [2] and this filter is usually used in the first stage of decimation, because it does not require the multipliers and the storage of coefficients. The efficient structure of the comb filter is known as CIC (Cascaded Comb-Decimator) and consists of the cascade of the integrators and differentiators separated by down sampling, as shown in Fig.2.

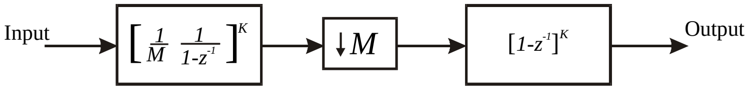

Figure 2. CIC filter.

The transfer function of the comb filter is given as

$$H_{COMB}(z)=\left[\frac{1}{M}\frac{1-z^{-M}}{1-z^{-1}}\right]^K, \tag{1}$$

where M is the decimation ratio and K is the number of cascaded CIC filters. However the corresponding magnitude response

$$H_{COMB}(e^{j\omega})=\left|\left[\frac{1}{M}\frac{\sin(\omega M/2}{\sin(\omega/2)}\right]^K\right|, \tag{2}$$

has an high passband droop and a low attenuation in the folding bands (bands around of zeros of the comb filter). The passband droop can significantly deteriorate the signal, as weel as the non attenuated aliasing in the folding bands. Consequently it is important to decrease the passband droop and to increase the attenuation in the folding bands. We consider here the pass band defined with the pass band frequency

$$\omega_p=\frac{\pi}{2M}, \tag{3}$$

and the folding bands defined as

$$\left[\frac{2\pi j}{M}-\omega_p;\frac{2\pi j}{M}+\omega_p\right];\ j=1,2,\ldots,M/2\,\cdot \tag{4}$$

Different methods have been proposed to improve the characteristics of the comb filter, [3]-[10].

The goal of this work is to improve the corresponding pass band and the attenuations in the folding bands of the comb filter, but without a significant increase of the comb filter complexity. To this end we propose to use the simple compensation filter and the sharpening technique. The rest of the paper is organized in the following way. Next section introduces the simple compensator and sharpening technique. The proposed method is described in Section 3 and illustrated with two examples.

2. COMPENSATION AND SHARPENING

We adopt the simple wideband multiplier-less comb compensator from [7],

$$H_{COMP}(z^M)=G^{K_2}(z^M), \tag{5}$$

where K_2 is the number of cascaded compensators, M is the decimation factor and

$$G(z^M)=-2^{-4}[z^{-M}-(2^4+2)z^{-2M}+z^{-3M}]\ . \tag{6}$$

Note that this filter can be moved to lower rate which is M times less than rate high input rate [7]. Additionally the filter does not require the multipliers but only 3 additions/subtractions, and does not depend on the decimation factor. The parameter K_2 depends on the comb parameter K, in the following way [7],

$$K_2 = \begin{cases} K & for \quad 1 < K \le 3 \\ K-1 & for \quad K > 3 \end{cases}. \tag{7}$$

To improve the magnitude characteristics of the filter, we propose to use the sharpening technique which can be used for simultaneous improvements of both the passband and stopband characteristics of a linear-phase FIR digital filter [11]. The technique uses the amplitude change function (ACF) which is a polynomial relationship of the form $Hsh = f(H)$ between the amplitudes of the overall and the prototype filters, Hsh and H, respectively. We propose to use simple sharpening polynomials in the form [11]

$$\begin{aligned} Sh\{H\}_1 &= 2H - H^2, \\ Sh\{H\}_2 &= 3H^2 - 2H^3, \end{aligned} \tag{8}$$

where Sh{} means sharpening.

3. DESCRIPTION OF THE METHOD

The proposed filter is the sharpened cascade of the comb filter (1) and the compensator filter (5),

$$H(z) = Sh\{H_{COMB}(z)H_{COMP}(z^M)\}, \tag{9}$$

where the sharpening polynomial is defined by (8).
The method is illustrated in the following examples.

Example 1: In this example we design the decimation filter for M=16 and K=5 using the first sharpening polynomial (8). According to (7) the parameter K_2=4. Figure 3 shows the corresponding magnitude responses of the proposed and comb filters. Pass band details confirm the considerable reduction of the pass band droop of the proposed filter. However the attenuation in the folding bands is slightly improved.

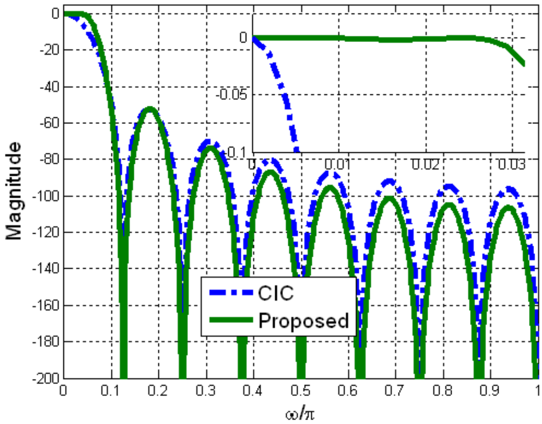

Figure 3. Illustration of Example 1.

Example 2: In this example we consider the second sharpening polynomial (8) and M=15, K=4, K_2=3. Figure 4 shows the overall magnitude responses and the passband zooms of the proposed and the comb filters.Note that the attenuation in the folding bands is considerably increased as an expense of slightly increased passband droop and the increased complexity.

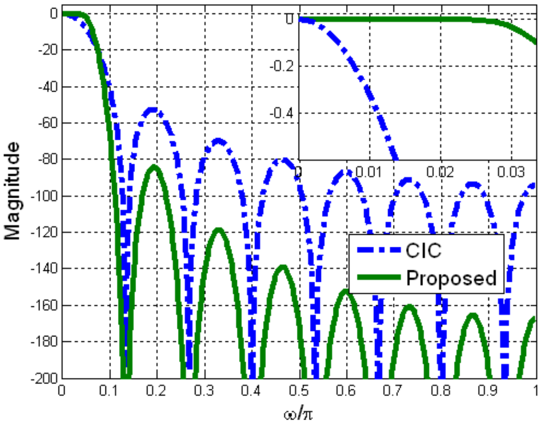

Figure 4. Example 2.

3. CONCLUSIONS

This paper presents novel comb-based decimator which considerably improves both the pass band and the stop band of the comb filter. The comb filter is cascaded with the simple compensator recently proposed in the literature, and the sharpening technique is used to simultaneously improve the pass band and the stop band of the comb filter. There is a trade-off between the choice of the sharpening polynomial and the obtained improvements. More complex polynomial also results in more complex filter.

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