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A Brief Review of Comb filter Design Techniques

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Abstract

The Comb filters are a class of optimized FIR filters also used for the purpose of decimation. The main objective of this survey paper is to study comb filters and compare various sharpening techniques. CIC filters are used for removing aliasing due to decimation and interpolation during the process of sample rate conversion. Comb filters because of low complexity filters are used for the operations of filtering the signal where sample rate conversion is required. FIR filters can be used for the process of decimation and are also known as non-recursive filters. The IIR filters can also be used for the purpose of decimation and known as recursive filters. The comb filters have a high droop in pass-band which is responsible for distortion of the incoming signal and also introduces stop-band attenuation in impulse response of filters. Various techniques have been designed for reducing pass-band droop as well as increasing attenuation in stop-band. The Sharpening technique improves attenuation in stop-band as well as improves droop in pass-band without increasing complexity of the circuit design. The sharpening technique improves both stop-band and pass-band by making multiple use of identical filter.

***Index Terms*—** Decimation, CIC Filter, Sharpening Low-pass Filters, Multiplier less linear base digital filter.

1. INTRODUCTION

The comb filter is the most popular decimation filter usually used in the first stage of the decimation Process. The popularity of the comb filter is due to its simplicity, its linear phase response and the fact that it does not need multiplications. Nevertheless, comb filters have a high pass band droop and a poor exhaustion in the so-called folding bands (bands around the zeros of comb filter) [1].

1.2 Decimation:

There is a continuous fashion to replace analog circuitry to digital. Advanced developments in Analogue to Digital (A/D) and Digital to Analogue (D/A) conversion procedure, based on delta sigma modulation are best example of the design trend of transferring more and more signal preparing tasks from the analog to the digital domain. This method avoid strong requirements for the analog anti aliasing filter, arising in a simpler analog filter design while requiring fast more typical digital structure. The oversampled rate must be minimized in the digital form. The process of decreasing sampling rate is called decimation and contains of two stages: filtering and down sampling by an integer, as shown in Fig.1 [2].

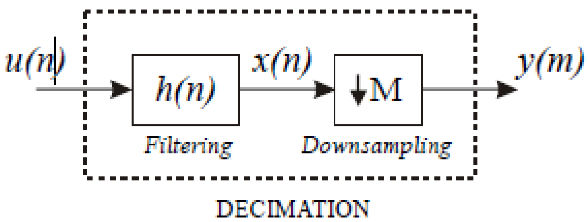

Figure 1. Decimation.

1.3 Multiplier less linear base digital filter:

Multiplier less linear-phase digital filters are very important in many practical applications including multirate filtering in wireless receivers.

1.3.1 CIC (Cascaded Integrated Comb-Decimator)

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

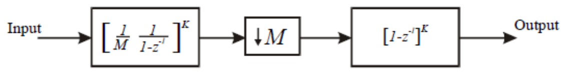

Figure 2. CIC filter.

There are two main problems in the application of comb filters in decimators:
1) The comb filter operates at the maximum sampling rate before any decimation takes place and consequently the power consumption of the comb filter is high.
2) The frequency response of the comb filter does not satisfy the design specifications [3].

1.3.2 Multiplier less Linear-Phase CIC 1D FIR Filter functions:

The normalized comb FIR filter function, in its non–recursive and recursive form, respectively, is defined as:

$$H(N,z) = \frac{1}{N}\sum_{i=0}^{N-1} z^{-i} = \frac{1-z^{-N}}{N(1-z^{-1})} \qquad (1)$$

Where N is a free integer parameter (is the number of coefficients of finite impulse response, that is, ( ) is the filter order). Causal low-pass CIC FIR filter functions, represented in the domain, are defined as:

$$H(N,K,z) = \left(\frac{1-z^{-N}}{N(1-z^{-1})}\right)^{K} \qquad (2)$$

Where K is the number of identical cascaded comb filter sections in classical CIC filter [4].

1.4Generalized Sharpening Technique:

1.4.1Sharpening Low-pass filters:

Filter sharpening is generally used to sharpen symmetric finite impulse response (FIR) filters. The transfer function of a symmetric FIR filter is:

$$G(z) = \sum_{k=-N}^{N} a_{|k|} z^{-k}.$$

Clearly:

$$G'(z) = \sum_{k=-N}^{N} (-k) a_{|k|} z^{-(k+1)}$$

and:

$$G'(1) = \sum_{k=-N}^{N} (-k) a_{|k|} = 0.$$

all low-pass symmetric FIR filters are members of the class of filters for which the sharpening technique is most helpful. The filter with transfer function is F(G(z)) will be more nearly ideal than the original filter. FIR filters are not the only members of that class; there is even a set of infinite impulse response (IIR) filters that are members of that class [5].

1.4.2 Application of the generalized sharpening to the two-stage comb decimator filter:

This filter takes advantage of two-stage decomposition of the comb Filter to apply the sharpening technique only in the second stage. The resulting transfer function is shown by:

$$H(z) = [H_1(z)]^L \cdot Sh_i \left[H_2(z^{M_1})\right]^K,$$

$$H_1(z) = \frac{1}{M_1} \cdot \frac{1-z^{-M_1}}{1-z^{-1}}, \quad H_2(z) = \frac{1}{M_2} \cdot \frac{1-z^{-M_2}}{1-z^{-1}},$$

Where $M = M1M2$ is the decimation factor, L and K are the number of cascaded filters $H1(z)$ and $H2(zM1)$ namely, and $Sh\{H(z)\}$ means that sharpening has been applied to $H(z)$. The value K must be even. The advantages of this approach are the following:

The down-sampling block M can be divided into two individual down-sampling blocks, $M1$ and $M2$. Since the first folding band, where the worst case attenuation occurs, is importantly determined by $H2(zM1)$, it is only required to apply sharpening to this filter. And stopband characteristics with minimum complexity than applying sharpening to the original single stage comb filter.

* The filter $H2(zM1)$ can be shifted after the down-sampling by $M1$, resulting in lower power consumption because $H2(z)$ works at a lower rate.

* The filter $H1(z)$ can work at a less rate after the down-sampling by $M1$ using polyphase decomposition[1]

LITERATURE SURVEY

Miriam Guadalupe Cruz Jimenez et al.(2013) A generalized sharpening technique to improve the magnitude characteristics of comb decimation filter in pass band and also in the folding bands is introduced in this paper. A two-stage comb filter is designed. The first stage can be operated at low sampling rate by using polyphase decomposition. A simple compensator is applied in the second stage to improve the pass band characteristic of the comb in the second stage. Then the generalized sharpening technique is implemented to decrease the pass band droop induced by the comb filter placed in the first stage. As outcome, a computationally efficient comb-based decimation filter is obtained which suggests better magnitude characteristics than previous proposed sharpening methods.

Gordana Jovanovic Dolecek et al.(2010) novel comb decimator Is presented in this paper. method is based on the pass band comb compensation and the sharpening procedure. The compensator is the simple multiplier less filter which can be moved to a lower rate which is M times low than the high input rate where M is the decimation factor. The parameters of compensator are independent of the decimation factor. The out coming filter is the multiplier less filter and exhibits the significantly decreased pass band droop, as well as the maximized attenuation in the folding bands, compared with the corresponding comb filter.

Gordana Jovanovic-Dolecek(2005) This paper presents a new sharpened comb decimator structure consisting of a cascade of a comb-filter dependent decimator and a sharpened comb decimator. The proposed realization scheme allows the sharpened section to perform at a lower rate that depends on the decimation factor of the first section. Using a polyphase decomposition, the sub filters of the first part can also be operated at this lower rate.

Dejan N. Milić(2014) This study presents a new class of particular low-pass multiplierless linear-phase special CIC FIR filter functions of low complexity given in an explicit cascaded compact form. Various examples of the proposed filters are illustrated. They are compared in a fair way with traditional CIC FIR filters for the equal values of group delay and the same number of cascade sections. An example of the new class of the suggested seventh order filter with nine cascades is presented, where its stops and attenuation has high value of 143.82 dB, where as corresponding conventional CIC FIR filter with the similar filter order and the number of cascades has only 115.18 dB.

Shlomo Engelberg(2006) this paper present a simple explanation of how filter sharpening doing and when it will not doing. We show that filter sharpening is more broadly applicable than previously noted. Author also shows that even when filter sharpening does not work in the accepted sense; it still improves the filter's performance.

D.E.T. Romero et al.(2013) The design of compensation filters for comb decimators using amplitude transformation is introduced. It is suggested that the transformation of cosine-squared filters provides good compensation properties. For a first-degree polynomial, the slope of the transformation line is specifically set as the specific compensator’s multiplier less coefficient. This coefficient modify proportionally with the increase of the comb pass band droop. Thus, the suggested method provides an impulsive and easy way of designing compensation filters.

G. Jovanovic Dolecek(2010) In this brief, we address the design of economical recursive concluded comb filters (GCFs) by suggesting an efficient technique to quantize the multipliers in the *z*-transfer function involving power-of-2 (PO2) terms. GCFs are effective anti-aliasing decimation filters with refined selectivity and quantization noise dismissal performance around the so-called folding bands with respect to classical comb filters. The suggested quantization technique assures perfect pole–zero cancelation in the rational *z*-transfer function of the GCFs, thus completely avoiding instability problems. Moreover, author suggests the use of a simple droop compensator for the gain of recovering the pass band droop distorting the important digital signal in the baseband. A design example is suggested with the aim of showing the application of the suggested technique, and a practical architecture of a sample third-order GCF is discussed.

Lila Haresh V.et al.(2014) This paper describes the generalized approach to design the wideband comb-based decimation filter in an effective multistage structure. In this design, we use the utmost flat second-order compensator and the filter sharpening technique. The out coming structure provides wideband compensation in the pass band area without degrading the attenuation in the aka bands of the comb filter. Here we assume the multistage comb based decimation filter, and each phase is compensated by particularly maximally flat second-order compensation filter. Last phase is realized by the sharpening technique and this sharpened phase will work at lower rate by the decimation factors of all before stages. A famous maximally flat second-order compensator is implemented. The polyphase separation is applied to non-recursive form of the comb filters which minimize the power utilization and to matchup the result with higher order compensation filter.

Ref. No.	Year	Tech/Method used	Findings
1	2013	A generalized sharpening technique(A two-stage comb filter) is used	A computationally efficient comb-based decimation filter is obtained which presents better magnitude characteristics
2	2010	novel comb decimator method is based on the pass band comb compensation and the sharpening technique	filter is the multiplier less filter and exhibits the significantly decreased pass band droop, as well as the increased attenuation in the folding bands
3	2005	cascade of a comb-filter based decimator and a sharpened comb decimator	This scheme allows the sharpened section to operate at a lower rate that depends on the decimation factor of the first section. Using a polyphase decomposition, the subfilters of the first section can also be operated at this lower rate.
4	2014	new class of selective low-pass multiplierless linear-phase special CIC FIR filter functions of low complexity given in an explicit cascaded compact form.	the filters can successfully replace popular conventional CIC filters in many applications such as audio applications, The multiplierless CIC FIR filter is also applicable in real-time applications
5	2006	expla-nation of how filter sharpening works and when it will not work	even when filter sharpening does not work in the accepted sense, it still improves the filter's performance
6	2013	compensation filters for comb decimators using amplitude transformation	approach provides an intuitive and easy way of designing compensation filters
7	2010	filters (GCFs) by choosing an efficient technique to quantize the multipliers in the *z*-transfer function employing power-of-2 (PO2) terms	quantization technique guarantees perfect pole–zero cancelation in the rational *z*-transfer function of the GCFs, thus totally avoiding instability problems
8	2014	the wideband comb-based decimation filter in an efficient multistage structure	The poly phase decomposition is applied to non-recursive form of the comb filters which reduce the power consumption and to compare the result with higher order compensation filter.

Conclusion

The comb filter is the most popular decimation filter mainly used in the first stage of the decimation process. The popularity of the comb filter is due to its lucidity, its linear phase reaction and the fact that it does not require multiplications. Because of a high pass band droop and a poor attenuation in the comb filters various techniques are suggested. One of the most useful approaches to improve concurrently the pass band and stop band characteristics of comb filters, contains of using the sharpening technique. Comb filter amplitude can be improved using two-stage comb filter. The design of compensation filters for the amplitude transformation have good compensation characteristics, a low complexity, and they can be used for narrowband as well as wideband comb compensation. Structure for a sharpened comb factor-of decimation filter has much better alias rejection than the corresponding comb filter and the original sharpened comb filter. new class of special low complexity low-pass selective multiplier less linear-phase CIC FIR filter functions replace popular conventional CIC filters in many applications such as audio applications. novel comb-based decimator which considerably maximizes both the pass band and the stop band of the comb filter.

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