Chapter 66
Methods for Improving Alias Rejections in Comb Filters

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ABSTRACT

Downsampling is the process of decreasing the sampling rate of signal by an integer. This process may introduce the unwanted spectrum replica called aliasing. To avoid aliasing, the signal must be filtered by decimation filter prior to downsampling. Decimation consists of filtering and downsampling. The simplest decimation filter is comb filter usually used in the first stage of decimation. However, comb filter does not provide a good aliasing rejection. This chapter presents methods for improving alias rejection of comb filters. The methods are based on comb zero rotation, cosine filters, Chebyshev polynomials, and cascade of combs with different parameters.

INTRODUCTION

Decimation is the process of decreasing the sampling rate by an integer M in the digital domain. This process is used in sub band coding, filter banks, communication systems, oversampled A/D (analog/digital) converters, among others. If the signal is not appropriately filtered, the unwanted replicas of the main spectrum of the decimated signal, called aliasing, will be present. Therefore, to prevent aliasing in the decimated signal, the signal must be first filtered by a low pass filter, called anti-aliasing, or decimation filter. As a result, the process of decimation consists of two principal stages: filtering and down sampling (decreasing the sampling rate by integer M). The integer value M is also called the decimation factor.

In order to avoid high order decimation filters, the decimation is usually performed in two or more stages. The most simple decimation filter is comb filter, (Hogenauer, 1981) which usually works at high input rate. The transfer function of the comb filter is given as:

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

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where K is the order of the comb, and z is a complex variable.

The magnitude characteristic of the comb filter, expressed in digital frequency ω, is given as:

$$\left|H(e^{j\omega})\right| = \left|\frac{1}{M}\frac{\sin(\omega M/2)}{\sin(\omega/2)}\right|^{K} . \tag{2}$$

The magnitude characteristic must be flat in the pass band of interest. Additionally, in order to eliminate aliasing, the comb filter must have a high attenuation in the so called folding bands, which are the bands around the zeros of the comb filter.

BACKGROUND

A simple method to increase the attenuation in the comb folding bands consists of increasing the order of the comb filter, as shown in Figure 1. Here, the decimation factor M is 10 and the values of order K are 1, 3, and 5. The zooms in the pass bands in Figure 1 show that the pass band droop increases with the increase of the order of the comb filter.

The objective of this article is to present the methods proposed so far to increase the bandwidths around the comb zeros, and thus increase the comb alias rejection.

Figure 1. The overall comb magnitude characteristics and the pass band zooms for M=10 and different filter orders