Chapter II

Multirate Systems and Filter Banks

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INTRODUCTION

During the last two decades, multirate filter banks have found various applications in many different areas, such as speech coding, scrambling, adaptive signal processing, image compression, signal and image processing applications as well as transmission of several signals through the same channel (Malvar, 1992a; Vaidyanathan, 1993; Vetterli and Kovacevic, 1995; Fliege, 1994; Misiti, Misiti, Oppenheim and Poggi, 1996). The main idea of using multirate filter banks is the ability of the system to separate in the frequency domain the signal under consideration into two or more signals or to compose two or more different signals into a single signal.

When splitting the signal into two or more signals an analysis-synthesis system is used. The analysis-synthesis systems under consideration in this chapter are critically sampled multi-channel or \( M \)-channel uniform filter banks and octave filter banks as shown in Figures 1(a) and 1(b), respectively. In the analysis bank of the uniform bank, the signal is split with the aid of \( M \) filters \( H_k(z) \) for \( k = 0, 1, \ldots, M-1 \) into \( M \) bands of the same bandwidth and each sub-signal is decimated by a factor of \( M \). In the case of octave filter banks, the overall signal is first split into two bands of the same bandwidth and both sub-signals are decimated by a factor of two. After that, the decimated lowpass filtered signal is split into two bands and so on. Doing this three times gives rise to a three-level octave filter bank corresponding to the structure shown in Figure 1(b). In this case, \( H_0(z) \) is a highpass filter with bandwidth equal to half the baseband and the decimation factor is 2, \( H_1(z) \) and \( H_2(z) \) are bandpass filters with bandwidths equal to one-fourth and one-eighth of the baseband, respec-
Figure 1: Analysis-synthesis filter bank. (a) M-channel uniform filter bank. (b) Three-level octave filter bank. Note that in the case of interpolation by a given factor, the corresponding filter should approximate this factor in the passband in order to preserve the signal energy.

In many applications, the processing unit corresponds to storing the signal into the memory or transferring it through the channel. The main goal is to significantly reduce, with the aid of proper coding schemes, the number of bits representing the original signal for storing or transferring purposes. When splitting the signal into various frequency bands with the aid of the analysis filter bank, the signal characteristics are different in each band and various numbers of bits can be used for coding and decoding the sub-signals. In some applications, the processing unit is used for treating the sub-signals in order to obtain the desired operation for the output signal of the overall system. A typical example is the use of the overall system for making adaptive signal processing...
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