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Design of Quadrature Mirror Filter: A Survey

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Abstract: - In this paper, a comprehensive survey on designing of Quadrature mirror filter based on poly phase structure is presented. A common approach to construct such filter-banks is to employ a two channel quadrature-mirror filter (QMF) bank with FIR analysis and synthesis filters. Filters of high degree are required to achieve a steep transition band and a high stop band attenuation, which results in a high computational complexity and a high system delay If QMF bank is free from aliasing distortion, amplitude distortion and phase distortion, it is said to have perfect reconstruction. If an alias-free filter bank has no magnitude and phase distortion, then it is called a perfect reconstruction (PR) QMF bank. Here, we present the different approaches adopted by different authors to design the quadrature mirror filter based on poly phase decomposition. In space applications solar panels and robotic arms introduce flexible modes in the system. To identifying frequencies of disturbances in flexible systems using advanced Digital Signal processing techniques such as filter banks and Quadrature Mirror Filters is introduced. Table summarize the different approaches for the design of QMF filter and the effectiveness of different approaches.

Keywords: **quadrature-mirror filter (QMF), poly phase decomposition, Analysis and synthesis filter.**

I. INTRODUCTION

During the last two decades, there has been substantial progress in multirate digital filters and filter banks. This includes the design of quadrature mirror filters (QMF). A two-channel QMF bank is extensively used in many signal processing fields such as sub band coding of speech signal, image processing, antenna systems, design of wavelet bases, and biomedical engineering and in digital audio industry [1]-[3]. During last two decades, quadrature mirror filter banks have been extensively used in sub-band coding of speech signals, image processing and trans-multiplexers [4][5]. Originally, the concept of QMF is introduced for removing aliasing distortion in speech coding.

In Digital Signal Processing, a Quadrature Mirror Filter is a filter most commonly used to implement a filter bank that splits an input signal into two bands. Among the various filter banks, two-channel QMF bank [1]-[2] was the first type of filter bank used in signal processing applications for separating signals into sub-bands and reconstructing them from individual sub-bands.

Quadrature mirror filter (PQMF) banks [8] have been widely used to decompose 2-D signals into directional components required for the directional sub band coding of image and video data [1]. QMF filter are used in many speech and communication application [2][3].

In several applications, in order to be able to estimate the frequencies of sinusoids hidden in noise, there is a need to decompose the original signal into its subcomponents. This process, called “analysis,” is the first part in the signal decomposition with “filter banks.” The other part, called “synthesis,” is the assembling of the decomposed signal again into one signal. The exactly reversed procedure is performed by the “transmultiplexers”.

Digital filter bank finds wide applications in many areas of signal processing such as TMUX, wireless communication channel, sub-band coding and acoustic echo cancellation. Because of such wide application, many researchers have given a lot of attention in efficient designing of filter bank. Filter bank is formed by parallel combination of band pass filters, which decompose incoming signal into number of sub-band signals and process them a tone end, opposite to normal case where the sub- band signals get recombined and reconstructed the output signal. It deals with processing of the signal at different sampling rate at different nodes of system.

In this paper, a comprehensive survey on designing of Quadrature mirror filter based on poly phase structure is presented. Here, we present the different approaches adopted by different authors to design the quadrature

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mirror filter based on poly phase decomposition. In space applications solar panels and robotic arms introduce flexible modes in the system. To identifying frequencies of disturbances in flexible systems using advanced Digital Signal Processing techniques such as filter banks and Quadrature Mirror Filters is introduced. Table summarize the different approaches for the design of QMF filter and the effectiveness of different approaches.

This paper is organized as follows: In Section II, quadrature mirror filter bank is explained in detail with detail description of the analysis and synthesis bank. Some application of the quadrature mirror filter is also presented in section III. Section IV presents the QMF bank using poly phase component. In Section V, present the comprehensive study of different approaches presented by different authors for the designing of Quadrature mirror filter. Finally, a conclusion is made base on this study.

II. QUADRATURE MIRROR FILTER BANK

QMF bank is a two-channel filter bank, which consists of analysis filters, down-samplers at transmission end, and up-samplers and synthesis filters at receiving end. The block diagram of QMF bank is shown in Fig.1. In QMF a discrete-time signal $x[n]$ is split into a two sub-band signals having equal bandwidth, using low-pass and high-pass analysis filters H_0 (Z) and H_1 (Z) respectively. These sub-band signals are down sampled by a factor of two to achieve signal compression or to reduce complexity. At output side, the two sub-band signals are interpolated by a factor of two and passed through low-pass and high-pass synthesis filters F_0 (Z) and F_1 (Z), respectively.

If the down-sampling and up-sampling factors are equal to or greater than the number of bands of the filter bank, then the output $y[n]$ can be made to retain some or all of the characteristics of the input signal $x[n]$ by choosing appropriately the filters in the structure It means for perfect reconstruction up-sampling or down-sampling factors should be equal to or greater than the no of sub-band in the QMF. If the up-sampling and down-sampling factors are equal to the number of bands, then the structure is called a critically sampled filter bank. The most common application of this scheme is in the efficient coding of a signal $x[n]$.

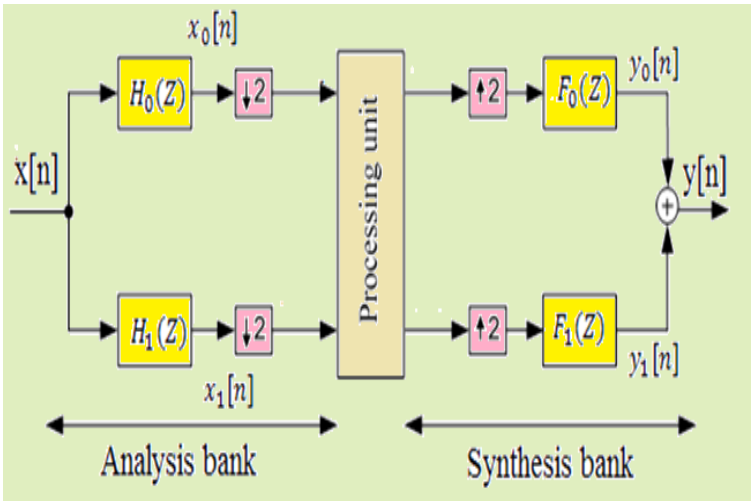

Fig. 1.QMF bank

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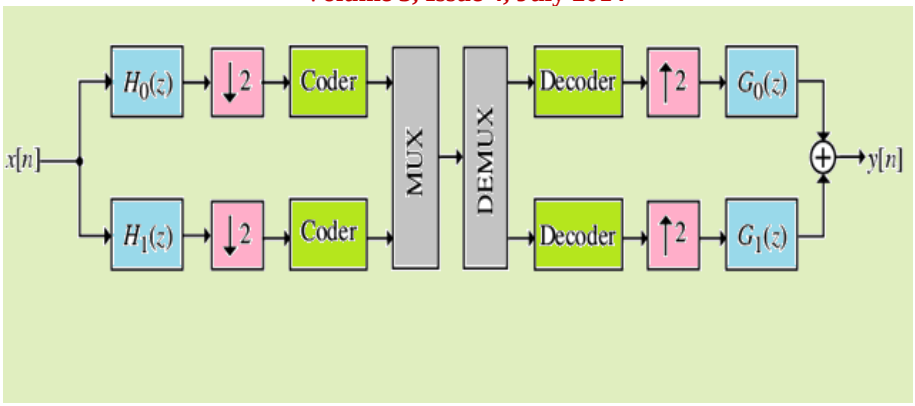

Fig. 2 Two-channel QMF bank-based sub band codec.

III. APPLICATION OF QUADRATURE MIRROR FILTER BANKS

Quadrature Mirror Filter Banks find applications in many signal processing fields, such as

1. Design of wavelet bases
2. Image compression
3. Digital trans-multiplexers used in FDM/TDM conversion
4. Discrete multi-tone modulation systems
5. ECG signal compression
6. Antenna systems
7. Digital audio industry
8. Biomedical signal processing
9. Equalization of wireless communication channels
10. Analog voice privacy systems.

IV. QMF BANK USING POLY-PHASE COMPONENT

The QMF bank can be realized efficiently by using poly-phase structure, which enables us to rearrange the computation of the filtering operation. For decimation filter, if direct form implementation is used then only the even numbered O/P samples are computed and this computation requires (N+1) multiplication per unit time (MPUs) and N addition per unit time (APUs). However during the computation of odd numbered O/P samples, the structure is merely resting.

If we use poly-phase implementation then the computation of O/P samples requires (N+1)/2 MPUs and N/2 APUs. The multipliers and adders in each of the filter *E0* (*z*) and *E1* (*z*) now have two units of time for doing their works and they are continually operative and no resting time. Thus poly-phase representation of decimation filters, as shown in Fig.3, reduces the computational complexity of the multipliers and adders in filter bank.

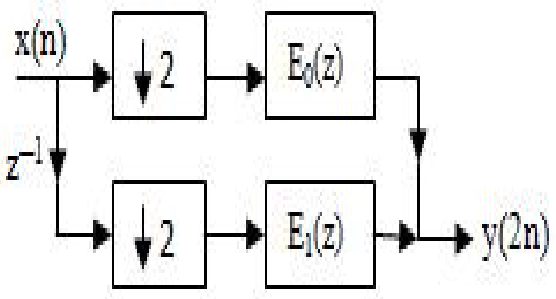

Fig.3 Poly-phase representation of decimation filters

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V. COMPREHENSIVE SURVEY ON THE DESIGNING OF QUADRATURE MIRROR FILTER

Table shows the detail of the work done by different authors in the field of designing of Quadrature mirror filter based on poly phase structure.

Year of Publication	Author	Title	Approach	Effects and solution
1999	Chee-Kiang Goh, Lim, Y.C., Chun Sum Ng	Improved weighted least squares algorithm for the design of quadrature mirror filters [6]	Weighted least squares (WLS) algorithm	A new term is incorporated into the objective function that effectively prevents an optimization algorithm from producing suboptimal QMFs. These suboptimal QMFs exhibit a transition band anomaly; the frequency responses of the filters have large oscillatory components in the transition band.
2001	Lawson, S.S., Klouche-Djedid, A.	Technique for design of two-channel approximately linear phase QMF filter bank and its application to image compression [7]	All pass sections	the two-channel QMF filter bank based on allpass sections is one of the best known circuits for building up a multi-channel filter bank for signal compression. An analysis-synthesis combination can satisfy two of the three perfect reconstruction (PR) conditions. The phase condition can be met to any desired accuracy.
2005	Uppalapati, H., Rastgar, H., Ahmadi, M., Sid-Ahmed, M.A.	Design of quadrature mirror filter banks with canonical signed digit coefficients using genetic algorithm [8]	Genetic algorithm (GA)	A unique genetic algorithm (GA) is developed to optimize filter bank coefficients. The proposed restoration technique maintains the specified word length and the maximum number of nonzero digits in the filter bank coefficients.
2009	Chimin Tsai	Two-Channel Perfect Reconstruction Filter Banks Using Hilbert Transformers [9]	Zero phase half-band filter	A design of perfect reconstruction QMFB by decomposing a zero phase half-band filter into a pair of conjugate mirror filters. The related QMHT is obtained by applying the frequency shift to the zero phase half-band filters before the decomposition.
2010	Ju-Hong Lee, Yuan-Hau Yang	Two-Channel Parallelogram QMF Banks Using 2-D NSHP Digital All-Pass Filters [10]	Two-dimensional recursive digital all-pass filters (DAFs) with nonsymmetric half-plane (NSHP)	This PQMF bank provides approximately linear-phase response without magnitude distortion. The design problem of this PQMF bank is appropriately formulated to result in a minimization of the linear-phase error associated with the 2-D NSHP DAFs in the pth-norm (L_p) sense.
2011	Gupta, A., Agarwal, S.K.	Designing of two channel polyphase quadrature mirror filter bank using power optimization method [11]	Poly phase components	The design problem is formulated to minimize an objective function, which is a linear combination of pass-band error and stop-band residual energy of the low-pass analysis filter of the filter bank.
2012	Anurag, S., Kumar, A.	Non-uniform filter bank design using modified window functions [12]	Modified window such as Kaiser, Cosh and Exponential.	These windows are modified by adding third parameter (ρ) which improves the spectral characteristic of the window in terms of smaller ripple ratio (RR), the wider main lobe width with improved side lobe roll-off ratio (SR). The cut-off frequency is varied

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				iteratively in order to adjust the filter coefficients so that the reconstruction error is optimized to zero.
2012	Narang, S.K., Ortega , A.	Perfect Reconstruction Two-Channel Wavelet Filter Banks for Graph Structured Data [13]	Arbitrary finite weighted undirected graph	Fourier decomposition, signal filtering and downsampling can be extended to graph domain. This property of bipartite graphs, allows us to design critically sampled two-channel filter banks, and we propose quadrature mirror filters for bipartite graph which cancel aliasing and lead to perfect reconstruction.
2013	Stanciu, L., Stanciu, V., Stanciu, C.	B-spline approach for the design of quadrature mirror filters [14]	symmetric B-spline functions	It was shown that linear phase FIR filters cannot exactly satisfy the condition that the squared amplitude frequency responses are mirror images of each other about the line $\omega = \pi/2$ which has led to the name quadrature mirror flters. The solution is to approximate the response of each frequency band by using B-spline functions, which insures continuous superior order derivatives.

VI. CONCLUSIONS

In this paper, a comprehensive survey on designing of Quadrature mirror filter based on poly phase structure is presented. A common approach to construct such filter-banks is to employ a two channel quadrature-mirror filter (QMF) bank with FIR analysis and synthesis filters. Here, we present the different approaches adopted by different authors to design the quadrature mirror filter based on poly phase decomposition. Table summarize the different approaches for the design of QMF filter and the effectiveness of different approaches.

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