行政院國家科學委員會專題研究計畫 期中進度報告

多媒體影音高階處理,傳輸及設計--子計畫二:應用於多媒體影音處理的無限脈衝響應副頻帶濾波器組之設計(2/3)

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計 畫 類 別 ： 整合型
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計 畫 主 持 人 ： 李枝宏

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行政院國家科學委員會補助專題研究計畫期中成果報告

應用於多媒體影音處理的無限脈衝響應副頻帶濾波器組之設計

(2/3)

Design of IIR Subband Filter Banks for Processing of Multimedia Image and Audio Signals (2/3)

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計畫主持人： 李枝宏

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本成果報告包括以下應繳交之附件：

□赴國外出差或研習心得報告一份

□赴大陸地區出差或研習心得報告一份

□出席國際學術會議心得報告及發表之論文各一份

□國際合作研究計畫國外研究報告書一份

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中　華　民　國　96 年 5 月　25 日

應用於多媒體影音處理的無限脈衝響應副頻帶濾波器組之設計(2/3)

Design of IIR Subband Filter Banks for Processing of Multimedia Image and Audio Signals (2/3)

計畫編號：NSC 95-2221-E-002-187

執行期限：95 年 8 月 1 日至 96 年 7 月 31 日

主持人：李枝宏　國立臺灣大學電機工程學系暨研究所教授

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一、中文摘要

本計劃已完成預期之研究工作一基於L_∞最佳化準則的IIR具有低相位延遲之鏡像對稱與非均勻副頻帶濾波器組之理論與設計，基於最小尖波誤差準則IIR濾波器止帶響應之設計理論，在本項研究內，我們研發基於L_∞最佳化理論設計以IIR濾波器為架構具有線性相位且低相位延遲之鏡像對稱與非均勻之副頻帶濾波器組理論與設計技術。在理論上，研究推導IIR具有線性相位且低相位延遲之鏡像對稱與非均勻之副頻帶濾波器組的系統架構模型。然後，研發設計此副頻帶濾波器組的最佳化技術。電腦模擬實驗已驗證本計畫成果之有效性。

關鍵詞：無限脈衝響應濾波器、鏡像對稱與非均勻副頻帶數位濾波器組。

二、英文摘要

This project has accomplished research work for the development of the theory and system structure of IIR quadrature mirror filter (QMF) banks and nonuniform-division filter (NDF) banks with linear phase and low group delay response. Utilizing an approximation scheme and an iterative algorithm, we have developed a method to design a two-channel QMF bank and a two-channel NDF bank with continuous coefficients in the sense of minimum peak reconstruction error and minimum stopband error criteria for analysis filters. It is shown that the optimal filter coefficients can be obtained by solving only linear equations. In conjunction with an iterative algorithm, a method is then presented to obtain the desired design result. The effectiveness of the proposed design technique is demonstrated by several simulation examples.

Keywords: IIR Filters, Subband Filter Banks。

三、緣由與目的

Due to the fact that multimedia

information becomes a necessary part of modern life, processing the audio or image signals of multimedia information has been viewed as an important research work. To deal with the difficulty of large data capacity required for transmitting multimedia signals, one of the possible remedies is to develop advanced digital signal processing technology for reducing the required information regarding the audio and image signals. In other words, the techniques of bandwidth compression and decompression, coding and decoding should be considered. Using subband filter banks has been recognized as an efficient approach for achieving the above purposes. Most of conventional design techniques consider the design of quadrature mirror filter (QMF) banks using finite impulse response (FIR) filters with some kind of symmetry in filter coefficients to keep the linear phase response. However, the system delay of the designed QMF bank is determined by the lengths of the FIR filters used; hence, the long overall system delay of a QMF bank with linear-phase FIR analysis filters may prohibit practical applications for processing multimedia signals. Therefore, it is worth investigating the design of IIR QMF banks with low group delay. In this three-year research project, we have been focused on the development of design theory for subband filter banks with low group delay. Based on several useful optimization criteria, we will develop efficient techniques for designing the subband filter banks to achieve the goals of minimizing peak magnitude and group delay errors for processing audio and image signals of multimedia data

四、研究方法

First, the QMF banks with a low group delay response for realization is developed。 Then, a method is developed based on an approximation scheme for designing a continuous-coefficient QMF bank with optimal reconstruction response and stopband response for its linear-phase (LP) IIR analysis and synthesis filters in the L_∞ sense. This method is further incorporated with an iterative algorithm to optimally design QMF banks with L_∞ reconstruction response and L_∞ stopband response for analysis and synthesis filters. It has been shown that the design method can achieve satisfactory design results. Next, the NDF banks with a low group delay response for realization is developed。A method is developed based on an approximation scheme for designing a continuous-coefficient NDF bank with optimal reconstruction response and stopband response for its linear-phase (LP) IIR analysis and synthesis filters in the L_∞ sense. This method is further incorporated with an iterative algorithm to optimally design NDF banks with L_∞ reconstruction response and L_∞ stopband response for analysis and synthesis filters. It has been shown that the design method can achieve satisfactory design results.

五、研究成果與討論

Here, we present simulation results of designing two-channel IIR QMF and NDF banks for illustration and comparison. These designs were performed on a personal computer with Pentium-IV CPU using MATLAB programming language. The performance for each of the designed IIR NDF banks is evaluated in terms of the perfect reconstruction error (PRE), the normalized peak stopband ripple of $H_i(z)$ ($NPSR_i$), the maximal variation of passband group delay of $H_i(z)$ ($MVPGD_i$), the maximal variation of the group delay (MVGD) in $\hat{T}(e^{j\omega})$, and the maximal variation of the filter-bank response (MVFBR). They are defined as follows:

PRE = max{ |20 $\log_{10}|\hat{T}(\omega_l)|$| }, for $\omega_l \in [0, \pi]$

$$NPSR_0 = -20\log_{10}\left(\max_{\omega_l\in[\omega_s,\pi]}\frac{|H_0(e^{j\omega_l})|}{\sqrt{LL_0}}\right) \text{ (dB)},$$

$$NPSR_1 = -20\log_{10}\left(\max_{\omega_l\in[0,\omega_p]}\frac{|H_1(e^{j\omega_l})|}{\sqrt{LL_1}}\right) \text{ (dB)},$$

$$MVPGD_0 = \max_{\omega_l\in[0,\omega_p]}\left|GD\{H_0(e^{j\omega_l})\}-\frac{1}{2}(N_1+N_2)\right| \text{ (samples)},$$

$$MVPGD_1 = \max_{\omega_l\in[\omega_s,\pi]}\left|GD\{H_1(e^{j\omega_l})\}-\frac{1}{2}(N_1+N_2)\right| \text{ (samples)},$$

$$MVGD = \max_{\omega_l\in[0,\pi]}\left|GD\{\hat{T}(e^{j\omega_l})\}-(N_1+N_2)\right| \text{ (samples)},$$

$$MVFBR = \max_{\omega_l\in[0,\pi]}\left|\hat{T}(e^{j\omega_l})-\frac{1}{2}e^{-j(N_1+N_2)\omega_l}\right|,$$

where $GD\{x\}$ denotes the group delay of x.

To perform the design process using the proposed technique for all design examples, the spacing for two adjacent frequency points in [0, π] is set to π/299. i.e., the number of grid points taken in [0, π] is 300. For the first QMF design example, the passband cutoff frequency ω_p and the stopband cutoff frequency ω_s of the required analysis filter are 0.4π and 0.6π, respectively. Moreover, the orders of the analysis filters are 3 and 2, respectively. For comparison, the design results of using the proposed technique and the techniques presented by [17] are also presented. For the second NDF design example, the real IIR DAFs $A_1(z)$ and $A_2(z)$ with orders N_1 and N_2 equal to 21 and 22, respectively, the low-pass analysis filter H_0(z) with a passband edge frequency $\omega_p = 0.3\pi$ and a stopband edge frequency $\omega_s = 0.5\pi$. For comparison, the design results of using the technique of [11] to design the same example are also presented. Table 1 lists the significant design results for the first example, while Table 2 shows the significant design results for the second example. From the presented design results, we note that the developed technique provides more satisfactory performance as compared to the techniques of [11] and [17]. The corresponding magnitude responses of the designed $H_i(e^{j\omega})$ are shown in Figure 1. The resulting phase error and group delay deviation of the designed NDF bank are depicted in Figures 2 and 3, respectively. Figure 4 plots the variation of the designed filter-bank response. In this project, we have developed a technique for the optimal design of two-channel QMF banks and NDF banks with linear-phase IIR filters and low group delay response. First, we formulate the design problem with continuous coefficients for the optimal criteria, namely, the minimum peak reconstruction error and the minimum peak filter stopband error. An approximation scheme has been utilized to achieve the design of optimal response behavior. In conjunction with an iterative algorithm, an efficient method to obtain an optimal design with low group delay response has been presented. The effectiveness of the proposed technique has been demonstrated by several design examples.

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***Table 1**: Significant design results for QMF Example*

	Proposed Technique	Technique of [17]
Filter orders	3, 2	3, 2
No. of filter coefficients	5	5
PSR (dB)	-19.93214	-18.05182
MVPGD	0.58315	0.60973
PRE (dB)	3.857×10^{-15}	5.785×10^{-15}
MVGD	1.47598	2.15794
MVFBR	0.10160	0.15095

***Table 2**: Significant design results for NDF Example*

	Proposed Technique	Technique of [11]
Filter order	22,23	10/10,11/11
No. of coefficients	45	44
PRE (dB)	2.7001×10^{-14}	0.0148
MVGD (samples)	0.0680	0.0583
$NPSR_0$ (dB)	33.80	32.21
$NPSR_1$ (dB)	33.79	32.07
$MVPGD_0$ (samples)	0.0340	0.0158
$MVPGD_1$ (samples)	0.0338	0.0230
MVFBR	2.28×10^{-3}	2.27×10^{-3}
No. of iterations	6	37

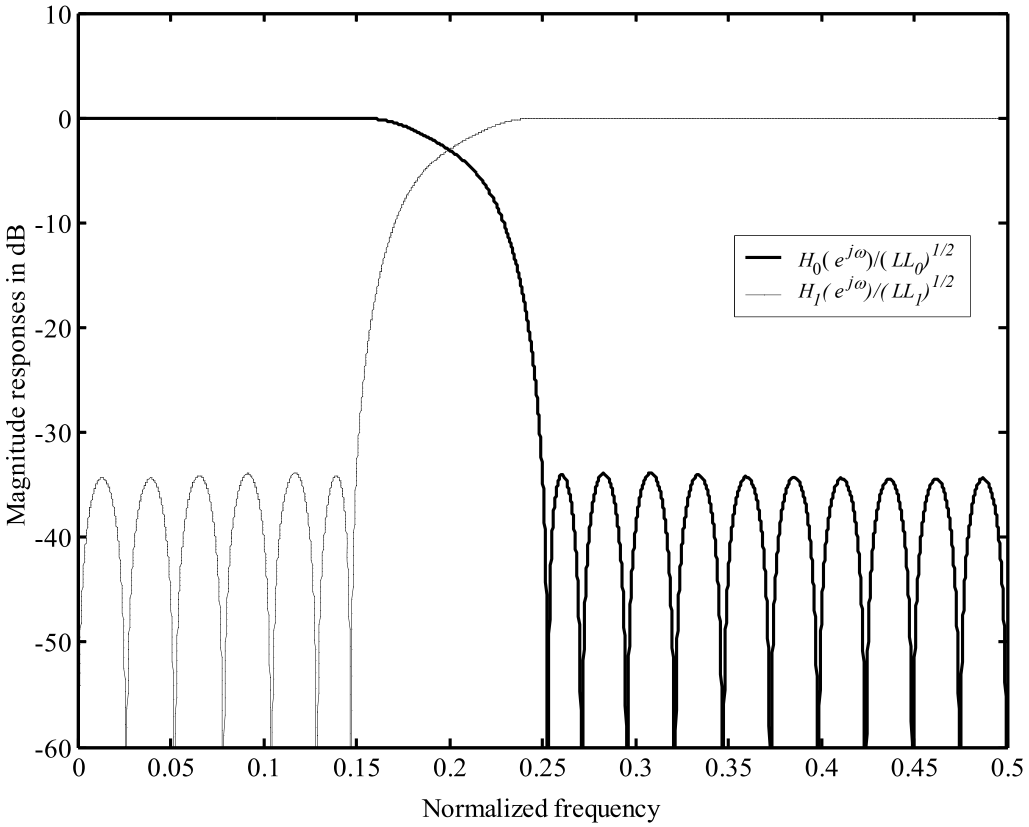

Figure 1. The magnitude responses of the designed analysis filters for *NDF Design*.

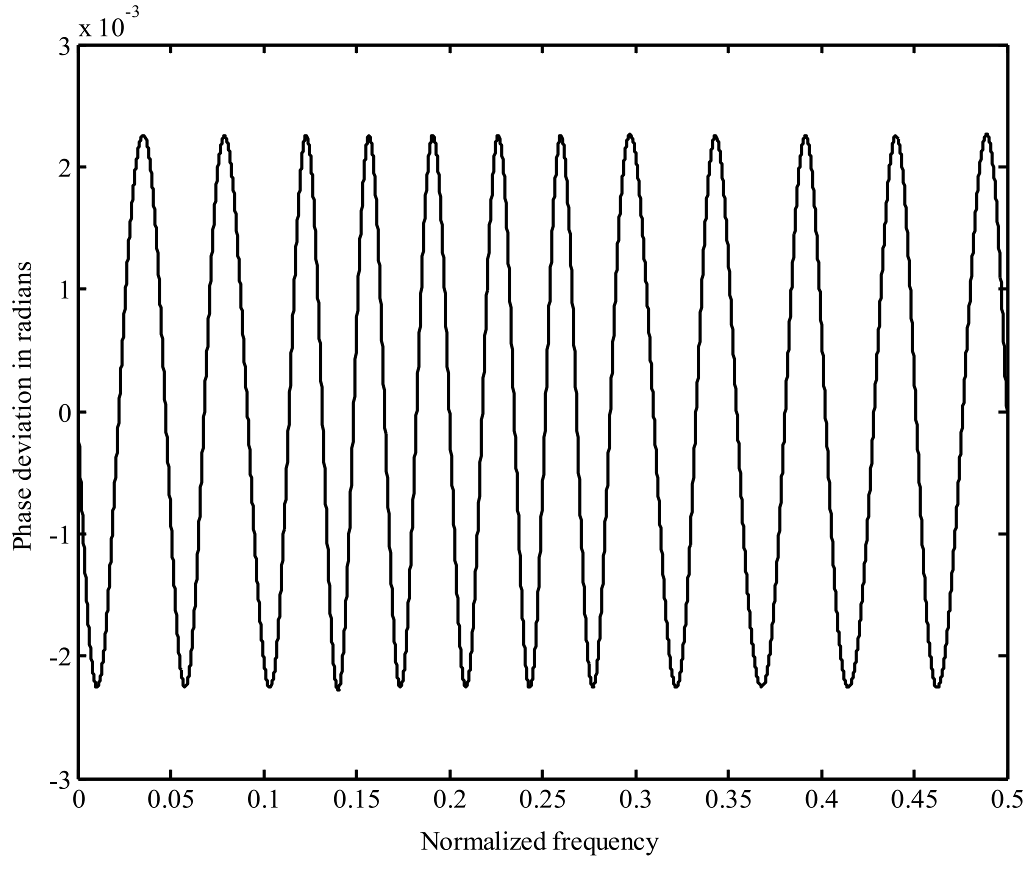

Figure 2. The phase error response of the designed NDF bank for *NDF Design*.

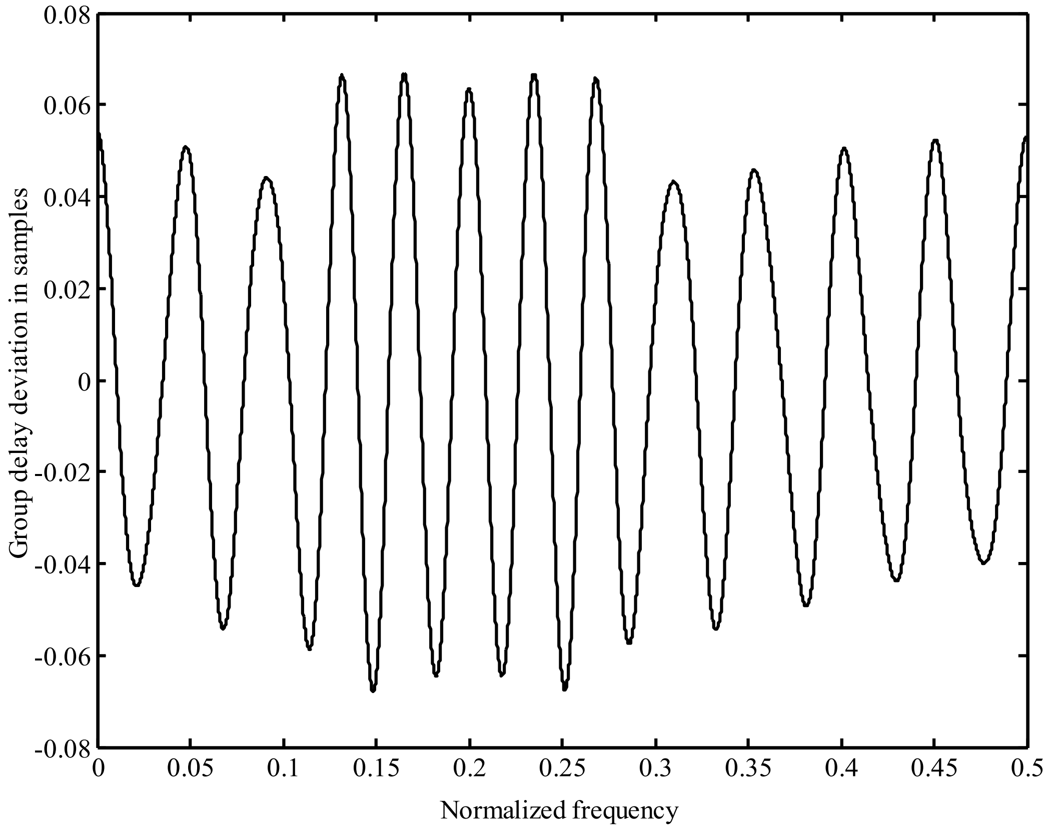

Figure 3. The group delay deviation of the designed NDF bank.

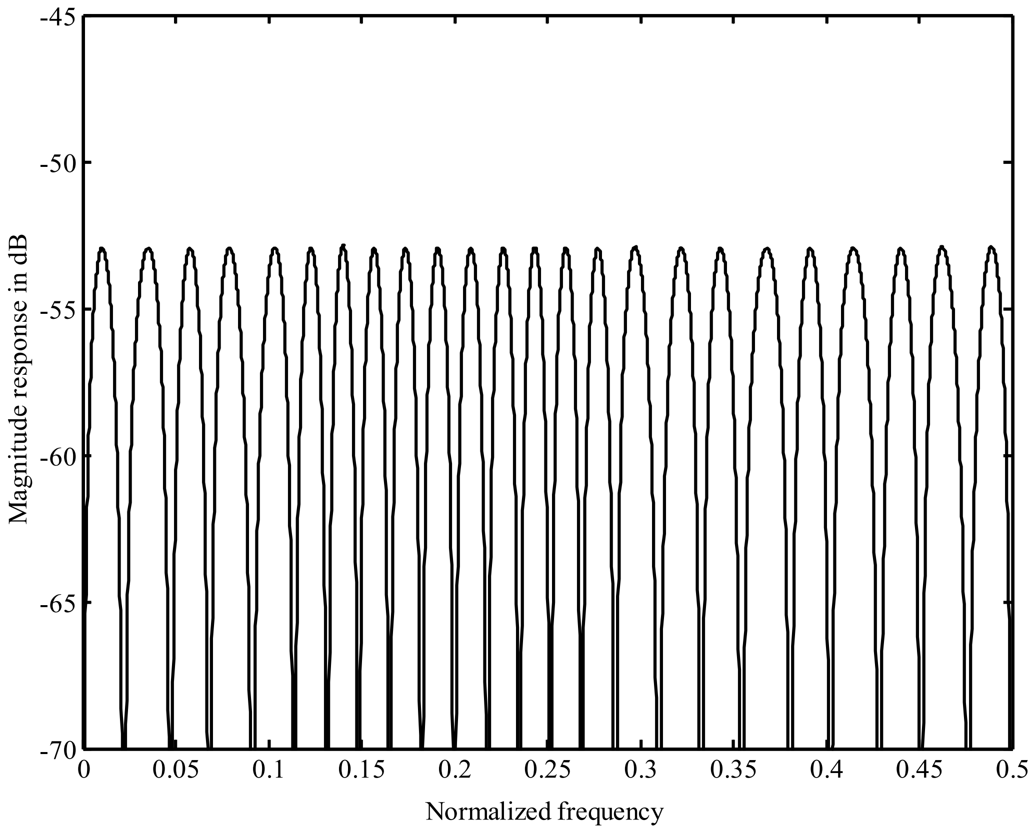

Figure 4. The variation response of the design NDF bank response.