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Design of Filter Bank Transmultiplexer System for Communication Using Different Modulation Technique

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Abstract— In this paper, design and comparative analysis outline strategy for trans-multiplexer (TMUX) system for communication with different windowing techniques are analyzed. In this scheme four adjustable window techniques viz., Blackman window, Saramaki window, Kaiser Window and ultra-spherical windows with different modulation techniques are used for designing a multi-channel filter bank trans-multiplexer FB-TMUX. A comparative study of performance of these four windowing functions with different modulation techniques such as Cosine, sine, complex and Extended lapped transform (ELT) for the recommended roll-off factor (RF) and stop band attenuation (A_s) is designed for trans-multiplexer is presented. The objective functions of the design to reduce Inter-symbol-interference (ISI) and specifically inter-channel-interference (ICI).

Keywords— Multirate, Filter Bank Transmultiplexer, Filter Bank, Extended lapped transform, ultraspherical window.

I. INTRODUCTION

Multi-rate signal processing deals with concepts, algorithms, and architectures as the body of material that embed sample rate change at one or more sited in the signal flow path and very useful for various branches of natural and artificial science, that involves data analysis and synthesis(Fredric J Harris, 2008; Mitra, 2001; Vaidyanathan, 1993). The changing sample rate ability within the processing stream presents a remarkable list of processing tricks and performance enhancements [1]. Multi-rate filter system play a substantial role in numerous signal processing applications such as data compression, scrambling, adaptive signal processing speech coding, detection of harmonics, de-noising, sub-band decomposition, recognition of one and two dimensional (2D) signals, adaptive filtering, design of wavelet bases, and wireless communication [2],[3],[4],[5],[6],[7]. Filter bank [FB] is a network of multi-rate bank of low pass, high pass and band pass filters; such filters are designed to cover a complete band in the frequency range. The filter bank consists of linear time-invariant systems, delays element, down samplers and up samplers. The main two modes of operation of filter banks on the basis of down sampling and up sampling are: first is analysis/synthesis mode and second one is synthesis/analysis mode. Analysis FB consists of sub-filters, which are known as analysis filters. Analysis filters are used to divide the input signal into dissimilar set of sub-band in frequency domain as shown in figure (a). Each sub-band comprises some frequency share of original signal. Similarly, the synthesis FB comprehends sub-filters called synthesis filters, which combine the sub-band signals and generate signal or reconstruct signal [8],[9]. First mode or Structure corresponds to the filter bank, which is used in source coding such as data compression, sub-band coding and the second mode corresponds to a trans-multiplexer (TMUX), which is used in channel equalization, channel coding etc. [10],[11]. These systems are basically exploited to convert time division multiplexed signals to frequency division multiplexed signals at the synthesis section and then back to time division multiplexed signals at the analysis section. TMUX systems can be derived from a filter bank structure, just by exchanging the role of analysis and synthesis filters. These structures can be further categorized into uniform TMUX and non-uniform TMUX. Uninform TMUX systems are used to transmit the signals having same bandwidth, while non-uniform TMUX are exploited to transmit the composite signals such as video signals and text signals having different sampling rates [12],[13]. Based on the reviewed literature on multi-rate system/filter banks or TMUX systems, for efficient design of a TMUX system, a number of TMUX systems are designed to minimize the overall cost and complexity of the system. Prototype filters are designed with the help of any optimization technique to minimize the objective function such as ICI or sum of ICI and ISI. Several designs were presented for efficient design of filter banks [14],[15],[16],[17],[18]. And TMUX systems based on linear search optimization proposed by Creusere and Mitra [19]. In these systems, either pass-band edge frequency or 3 dB cutoff frequency is optimized using a linear search optimization. Recently, authors have used windowing technique for the design of cosine modulated uniform TMUX system [20],[21],[22],[23].

Rest of the paper is organized as follows: section 1contains a brief introduction about the paper, section 2 gives an overview of the filter bank for trans-multiplexer, Section 3 presents proposed scheme i.e an efficient filter bank design algorithm for FB-TMUX system using different windowing function such as ultrasperical, Blackman, Kaiser, Saramaki and Kaiser Window for different modulation techniques. Section 4 contains proposed ELT modulation, finally results discussion in section 5 and section 6 contains conclusion.

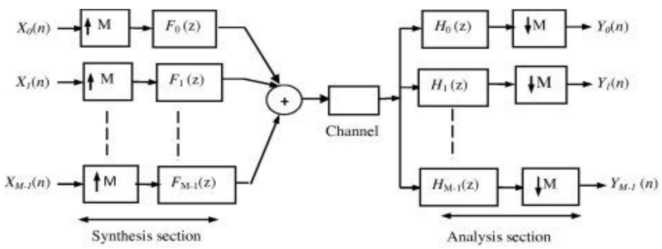

Figure 1. General block diagram of filter bank trans-multiplexer system

II.A BRIEF DISCUSSION ON FILTER BANK FOR TRANS-MULTIPLEXER

Generalized prototype of a multi-channel filter bank (FB) tree structure TMUX system is shown in figure 1 and similar parallel form of FB-TMUX system is given in the figure 2. TMUX system network are designed from a filter bank structure, just by exchanging the role of analysis and synthesis filters. These structures can be further categorized into uniform TMUX and non-uniform TMUX. Uninform TMUX systems are utilized to transmit the signals accruing the same bandwidth and non-uniform TMUX are exploited to transmit the composite signals such as text signals having different sampling rates and video signals. Based on the reviewed literature on multi-rate system/filter banks or TMUX systems for dynamic and efficient design of a TMUX system, a number of TMUX systems are designed to minimize the overall cost and complexity of the system. Prototype filters are designed with the use of much optimization techniques to minimize the objective function such as ICI and ISI. Several designs were presented for efficient design of filter banks and Creusere and Mitra in [24],[25],[26] proposed TMUX systems based on linear search optimization. In these systems either 3 dB cutoff frequency or pass-band edge frequency is optimized using a linear search optimization. Recently, authors have utilized various windowing techniques for the design of cosine modulated uniform TMUX system [27],[28],[29],[30].

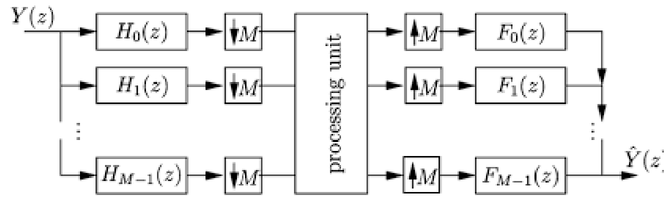

Figure 2. A block diagram of a parallel filter bank

III. MATHEMATICAL MODEL OF FILTER BANK TRANS-MULTIPLEXER SYSTEMS USING DIFFERENT WINDOWING TECHNIQUES WITH DIFFERENT MODULATION TECHNIQUES.

In this paper, four different window functions such as Blackman, Kaiser, Saramaki and Ultra-spherical windows are exploited for the design of proposed prototype system for trans-multiplexer systems due to closed form solution and less complexity using different modulation techniques. These four window functions are defined as [31],[32].

3.1 Kaiser Window

The Kaiser window is defined in discrete time domain as

$$w_k(n) = \begin{cases} \dfrac{I_0\left(\alpha_k\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{I_0(\alpha_k)} & for\ |N| \le \frac{N-1}{2} \\ 0 & otherwise \end{cases} \quad (1)$$

Where α_k is the adaptable parameter , $I_0(x)$ is the modified Bessel function of the kind of zero order, given as

$$I_0(x) = 1 + \sum_{k=1}^{\infty}\left[\frac{1}{k!}\left(\frac{x}{2}\right)^k\right]^2 \quad (2)$$

In equation (1), the parameter α_k can be computed as

$$\alpha_k = \begin{cases} 0.1102(A_s - 8.7); & for, (A_s > 50) \\ 0.5842(A_s - 21)0.4 + 0.07886(A_s - 21); & for, 21 \le (A_s) \le 50 \\ 0; & for, (A_s) < 21 \end{cases} \quad (3)$$

Order $(N-1)$ of a filter is calculated as

$$N - 1 = \frac{A_S - 7.95}{14.95\Delta f} \quad (4)$$

Where A_s is the stopband attenuation and $\Delta f = (\omega_s - \omega_p)/2$

3.2 Saramaki Window

Saramaki window is defined as

$$w(n) = V_0(n) + 2\sum_{k=1}^{N} V_k(n), \ \ 0 \le n \le N-1 \quad (5)$$

Where

$$V_0 = \begin{cases} 1, & n = 0 \\ 0 & otherwise \end{cases} \quad (6)$$

$$V_1(n) = \begin{cases} \gamma - 1, & n = 0 \\ \frac{\gamma}{2}, \quad |10| = 10, & otherwise \end{cases} \quad (7)$$

And

$$V_k(n) = \begin{cases} 2\,(\gamma - 1)v_{k-1}[n] - V_{k-2}[n] + \gamma\left[V_{k-1}[n-1] + V_{k-1}[n+1]\right], & -k \le n \le k \\ 0, & otherwise \end{cases} \quad (8)$$

In equation 7 and 8, γ is defined as

$$\gamma = \frac{1+\cos\frac{2\pi}{2N+1}}{1+c0s\,\frac{2\beta\pi}{2N+1}} \quad (9)$$

Where β is the adjustable parameter, calculated as

$$B= \begin{cases} 0.000121(A_s - 21)^2 + 1\;0.0224(A_s - 21) + 1\,; & for\ 21 \le A_s \le 65 \\ 0.033A_s + 0.062; & for\ 65 < A_s \le 110 \\ 0.0342A_s - 0.064; & for\ A_s > 110 \end{cases} \quad (10)$$

Order (N-1) of a filter is obtained using

$$N - 1 = \frac{A_S - 8.15}{14.36(\omega_S - \omega_p)/\pi} \quad (11)$$

3.3 Blackman Window

Blackman normalized window function is defines as

$$w(n) = \begin{cases} a_0 - a_1\ \cos\left(\frac{2\pi n}{N-1}\right) + a_2\ \cos\left(\frac{4\pi n}{N-1}\right) & \text{for} -(N-1)/2 \le n \le (N-1)/2 \\ 0 & otherwise \end{cases} \quad (12)$$

where

$$a_0 = \frac{1-\alpha}{2}; \quad a_1 = \frac{1}{2}; \quad a_2 = \frac{\alpha}{2}$$

3.4 Ultra-spherical Window

The coefficients of a right- sided ultra-spherical window can be calculated explicitly for an even or odd length N as

$$W(nT) = \frac{A}{p-n}\binom{\mu+p-n-1}{p-n-1}.\sum_{m=0}^{n}\binom{\mu+n-1}{n-1}\binom{p-n}{m}B^m \quad (13)$$

For n = 0,1,2,…,N – 1 [17].

$\binom{\alpha}{0} = \binom{\alpha}{\alpha} = 1\ because\ \binom{n}{k} = \binom{n}{n-k}. T$ represents the interval between the samples and

$$A = \begin{cases} \mu x_\mu^p & for\ \mu \ne 0 \\ x_\mu^p & for\ \mu = 0 \end{cases} \quad (14)$$

$$B = 1 - x_\mu^{-2} \quad (15)$$

$$P = N - 1 \quad (16)$$

In equation 13, μ, x_μ, and N are independent parameters and $w[(N-n-1)T] = w(nT)$, i.e the window is symmetrical.

A normalized window is obtained as $\hat{w}(nT) = \frac{\omega(nT)}{\omega(DT)}$.

Where $D = \begin{cases} \frac{N-1}{2} & for\ \ odd\ \ N \\ \frac{N}{2} - 1 & for\ \ even\ N \end{cases}$ (17)

IV. ELT FOR DESIGNING PROTOTYPE FILTER

Various modulation techniques based on Trans-multiplexer (TMUX) have been designed such as cosine modulation, sine modulation, complex exponential modulation and Extended lapped transformation trans-multiplexer (ELT-TMUX) [31],[32]. In this paper four window functions viz: Blackman, Kaiser, Saramaki and Ultra-spherical windows are used as window function for analysis on extended lapped transformation trans-multiplexer modulation technique.

Table 1. Performance of proposed method for designing FB-FBMC using different modulations Bands (M) =8, RF= 1.1

Modulation	**N**	**Band (M)**	**A_s (dB)**	**RF**	**ICI (dB)**	**ISI (dB)**	**SICI (dB)**	**SISI (dB)**	**SI (dB)**
Cosine	64	8	70	1.1	-250.92	-115.69	55.52	-79.7	-79.7
sine	64	8	70	1.1	-250.93	-115.69	55.52	-79.7	-79.7
complex	64	8	70	1.1	-246.23	-115.66	45.29	-85.28	-85.28
ELT	64	8	70	1.1	**-275.52**	-115.67	**57.28**	**-102.55**	**-102.55**

V. RESULTS

ELT is an adapted system of modulation lapped transform (MLT) having larger length of based functions as compared to complex exponential, cosine and sine modulation techniques. Due to that, ELT modulated filter have relatively better stop-band pass-band and transition band response. ELT is good for real time speech coding as compared to DCT based block transform. ELT based filters have significantly improved response. In Table 1, a comparative search of performance of the proposed design with earlier reported work is made. It is found that Ultra-spherical window with ELT shows a good performance as compared to other windowing techniques.

VI. CONCLUSION

In this paper, an improved design of filter bank trans-multiplexer with different windowing function using different modulation techniques for communication is proposed. Based on ELT with Ultra spherical window, system shows better results as compared to other windowing techniques. Proposed method provides lower values of ICI and ISI at different filter orders and roll off factors. Ultra-spherical window function with extended lapped transform modulation produces positive performance as compared to other windowing techniques.

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Authors Profile

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