DESIGN OF FILTER BANK TRANSMULTIPLEXER SYSTEM FOR COMMUNICATION USING DIFFERENT WINDOWING TECHNIQUES

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Abstract: In this paper, design and comparative analysis outline strategy for transmultiplexer (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 ultrasperical windows are used for construction a multi-channel prototype transmultiplexer. Designing of TMUX system with comparative study performance of these four windowing techniques for the recommended stop band attenuation (A_s) and roll-off factor (RF) with filter bank transmultiplerxer is presented. The objective function of the design to reduce Inter-symbol-interference (ISI) and specifically inter-channel-interference (ICI).

Keywords- **Multirate, Filter Bank Transmultiplexer, Filter bank, Window functions, Ultraspherical.**

1. Introduction

Multi-rate signal processing deals with conceptions, algorithms, and designing as the body of physics that embed with sample rate changes at one or more than one 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 capability inside the processing flow presents exceptional list of processing gimmicks and improved achievements [1]. Multi-rate based filter system plays a substantial role in numerous signal processing applications such as adaptive signal processing speech coding, data compression, scrambling, detection of harmonics, de-noising, sub-band decomposition, recognition of one and two dimensional (2-D) signals, adaptive filtering, design of wavelet bases, and wireless communication [2-7]. Filter bank system is a network of multi-rate filter banks of high pass, low pass and band pass filters; such filters are designed to cover an entire band of the frequency range. The filter bank consists of Linear time-invariant systems, delays element, down samplers and up samplers. The Main two mode of operation of filter banks on the basis of down sampling and up sampling are: first is analysis/synthesis mode and another one is synthesis/analysis mode [1]. 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 network Structure corresponds to the filter bank, which is used in source coding such as sub-band coding, data compression and the second mode of filter bank network corresponds to a transmultiplexer (TMUX), which is used in channel coding and channel equalization etc [9]. These systems are essentially exploited to convert time signal into frequency signals and vice versa. That is time division multiplexed signals to frequency division multiplexed signals at the synthesis section and then back to time division multiplexed signals from frequency division multiplexed signals at the analysis section [12-13]. This paper presents an improved method of algorithm for the prototype design of filter bank transmuliplexer (FB-TMUX) system using various window functions to reduce interferences. The paper is organized as follows: introduction part is in section 1 section 2 gives an overview of FB-TMUX, Section 3 presents an efficient prototype design algorithm for FB-TMUX system using different windowing function such as ultrasperical, Blackman, Kaiser, Saramaki and Kaiser Window, finally, results and discussion in section 4 and conclusion in section 5.

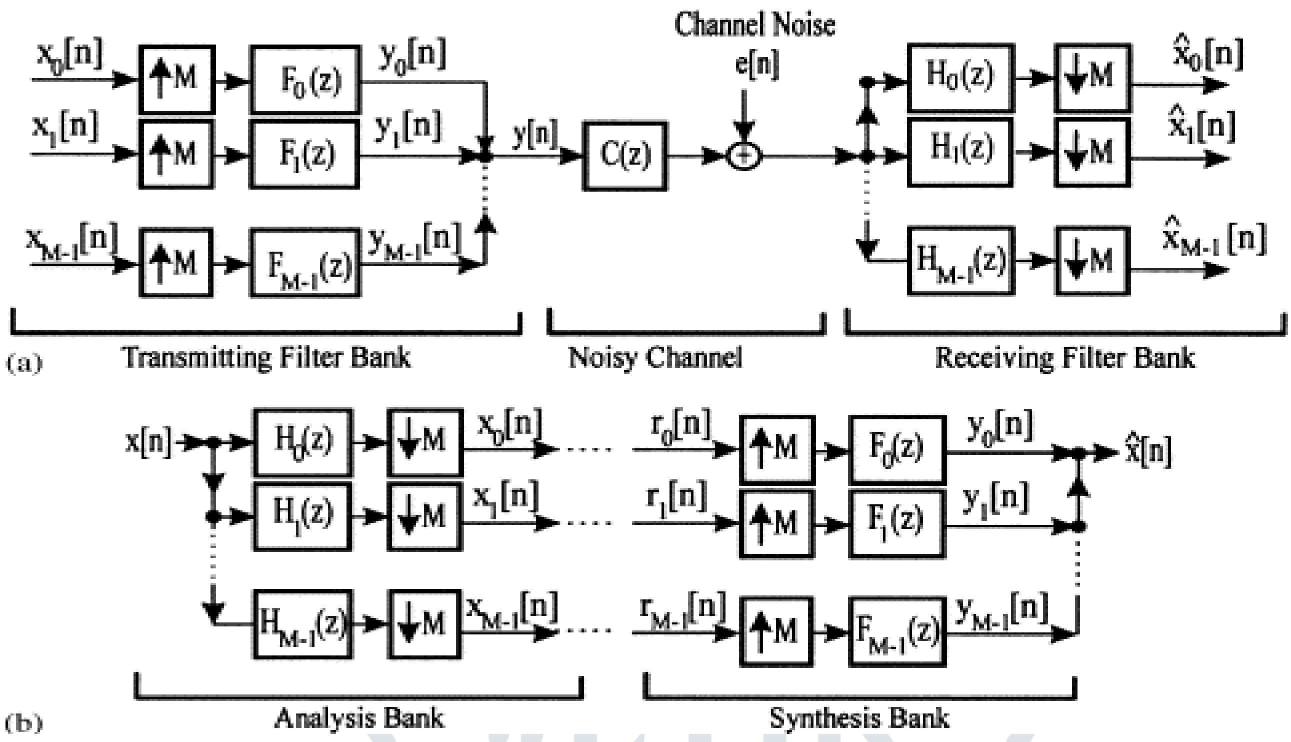

Fig.1. (a) A general block diagram of a TMUX system [2-3]. (b) A block diagram of a filter bank system [10-11].

2. A brief discussion on Filter bank TMUX

Generalized prototype of a multichannel filter bank (FB) tree structure TMUX system is shown in figure 1a and similar parallel form of FB-TMUX system is given in the figure 1b. 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 [12,13]. 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 [23–26] were presented for efficient design of filter banks and Creusere and Mitra [22] 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 in [27–30] have utilized various windowing techniques for the design of cosine modulated uniform TMUX system.

3. Improved Design of FB-TMUX Systems using different Windowing Techniques

In this paper, four different window functions such as: Blackman, Kaiser, Saramaki and Ultraspherical windows are exploited for the design of proposed prototype system for transmultiplexer systems due to closed form solution and less complexity. These four window functions are defined as [14-21].

3.1 Kaiser Window

The Kaiser window is defined in discrete time domain as [14,15]

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

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

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

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 [15]

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

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

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

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

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

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[18]

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

where

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

3.4 Ultraspherical Window

The coefficients of a right- sided ultraspherical window can be calculated explicitly for an even or odd length N as [16]

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

For n = 0,1,2,…,N – 1 [17]

$\binom{\alpha}{0} = \binom{\alpha}{\alpha} = 1\ because\ \binom{n}{k} = \binom{n}{n-k}$. T is 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 $$D = \begin{cases} \frac{N-1}{2} & for\ \ odd\ \ N \\ \frac{N}{2} - 1 & for\ \ even\ N \end{cases} \quad (17)$$

In this paper, filter coefficients of proposed filter design for a FB-TMUX are improved to 0.7071 adjusting 3 dB ω_c. Designing prototype filter for FB-TMUX, flowchart of the proposed algorithm is shown in figure 2. The steps are follows:

Step 1: Specify A_s and ω_c .
Step 2: Initialize step size and counter.
Step 3: Specify ideal for target.
Step 4: Compute the filter coefficients A_s and ω_c.
Step 5: if $|error| \le$ EL , stop algorithm otherwise move next step.
Step 6: if ICI < ideal then adjust the cutoff frequency by ω_c+*step*, else $\omega_c = \omega_c$-*step*
Step 7: Redesign the filter with new cutoff frequency, then calculate ICI and error at halved step size.
Step 8: Go to step 5 till satisfied error is not limited.

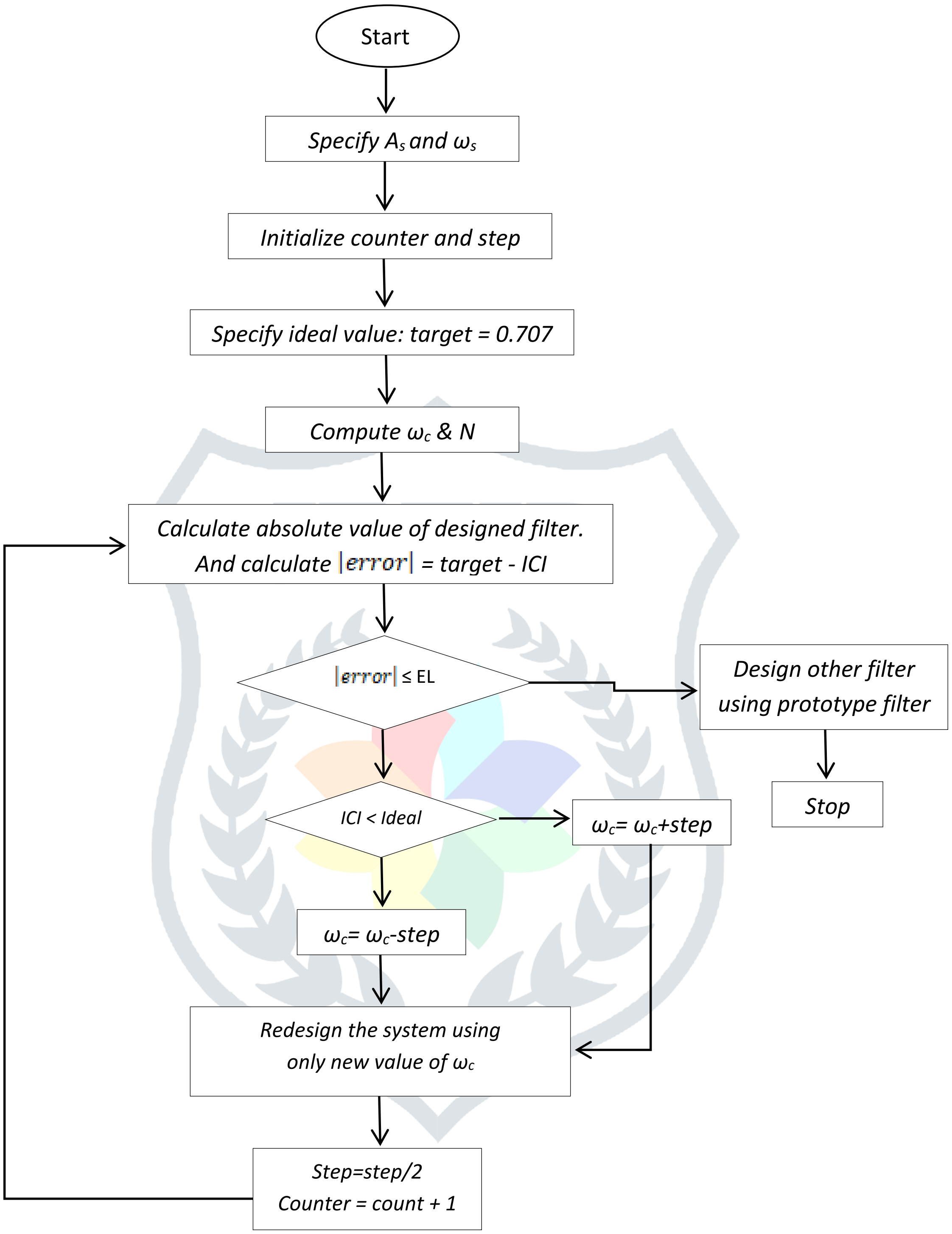

Figure 2 A proposed optimized algorithm

4. Results and discussion

In table 1, a comparative study analysis of performance of proposed prototype method and algorithm is made and inter channel interference (ICI) for four channel FB-TMUX taken as objective function. It is found that FB-TMUX systems have significantly smaller or decreased values of ICI and inter-symbol interference (ISI). The values of ICI and ISI given by proposed method are satisfactory, whereas ultraspherical window function shows better performance as compared to other windowing techniques.

Table 1. Performance of the proposed method for designing FB-TMUX using four window function

. Bands (M) =8, RF= 1.1

Window function	N	A_s (dB)	ICI(dB)	ISI(dB)	SICI(dB)	SISI(dB)	SI(dB)
Blackman	64	70	-259.69	-115.94	100.14	-43.65	-43.65
	124	75	-340.02	-115.89	178.21	-45.80	-45.80
Kaiser	64	70	-300.9	-115.67	93.30	-91.93	-91.93
	124	75	-312.8	-115.68	57.32	-103.39	-103.39
Saramaki	64	70	-276.39	-115.66	57.32	-103.39	-103.39
	124	75	-480.12	-115.67	271.93	-92.57	-92.20
Ultrasperical	64	70	-275.52	-115.68	57.28	-102.55	-102.55
	124	75	-489.80	-115.68	281.21	-92.92	-92.22

5. **Conclusion**

In this paper, an improved design of filter bank trans –multiplexer (FB-TMUX) with different windowing function for communication is proposed. The simulation results clearly illustrate that inter channel interference using adjustable ultraspherical window function significantly reduced as compared to Blackman, Kaiser and Saramaki windowing function at the same filter lengths 64 and 124.

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