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Design Of Cosine Modulated Filter Bank For Uniform Channelization

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Abstract. Traditional designs for non-uniform filter bank (NUFB) are usually complex which involves complicated nonlinear optimization with large number of parameters and lack of linear phase (LP) property. It is proposed that a Reconfigurable FIR cosine modulated filter bank is designed with linear phase characteristics for uniform and non uniform frequency spacing . Reconfigurability is achieved byCoefficient decimated multirate near perfect reconstruction (NPR) cosine modulated filter banks with uniform and non-uniform frequency spacing .This method involves the maximal decimation in the analysis and synthesis filter banks which leads to develop the optimized algorithm for the channelizer

Keywords: FIR Filters, Cosine modulation, Multirate filtering, multistage filtering, Channelization, Decimator, Interpolator, Sampling .

1. Introduction

In a typical SDR receiver, the channelizer extracts multiple radio channels of distinct bandwidths from a digitized wideband input signal using digital filter banks. [12]

The channelizer employed in a radio supporting this type of architecture must be flexible enough to accommodate all of the carrier/bandwidth combinations supported by the network architecture, and possibly allow for the dynamic reallocation of channel resources within this architecture during operation In traditional, the uniform band-pass filter banks are usually employed to achieve channelized filter in analog domain. Different signals arriving at the same time that have different carry frequency will be output from different band pass filters with different centre frequency. Every band pass filter is a channel in channelized receiver. The frequency accuracy is limited to the bandwidth of the band-pass filter.

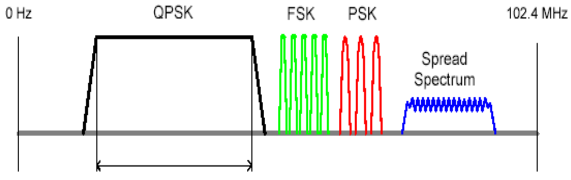

Fig.1 Frequency plan

Frequency transforms, such as the FFT, are special cases of channeliser designs[4]. They divide the input bandwidth into a number of evenly spaced frequency bands, commonly referred to as "bins", in order to allow the frequency content of an input signal to be analysed. An FFT can be considered as a simple channeliser that converts an input signal into N evenly spaced channels, where N is the length of the FFT .Uniform DFT-FB can be used because of low degree of complexity.

2. Review Of Filter Banks

2.1. Polyphase Filter Bank

The Polyphase filter bank consists of 2N independent FIR filters where N is the number of channels in the Polyphase-FFT system[7] . it is possible to expand H(z) in terms of M polyphase branches and it is possible to the polyphase implementation of prototype filter as mentioned in fig.2.1 makes reconfiguration tasks more tedious and expensive as it invokes updation of polyphase branches and the coefficients.

The polyphase filter is created through the decomposition of the low pass filter used to provide channel isolation on a per channel basis In general, the number of channels in this technique must equal the decimation rate, and as such the sampling rate must be a power of two times the baseband bandwidth.

2.2. Coeffecient Decimation Method Filter Bank

The filter bank based on this approach have absolute control over the passband width and passband locations [1]. In the CDM, N tap FIR filter in which the coefficients of a low pass FIR filter (termed as the modal filter) are decimated by M, i.e., every Mth coefficient is retained and the others replaced by zeros, to obtain a FIR filter with a multi-band frequency response. The frequency response of the resulting filter has bands with centre frequencies at 2πk/M, where k is an integer ranging from 0 to (M-1)[1]. CDM is used to obtain flexible filter banks for channelization PB widths and pass band centre frequency. the frequency response is obtained by scaling the coefficients by M = 2. The stopband attenuation reduces as M increases.the transition band width remains unaltered for any M.

After performing CDM-I by decimation factor M, if all the retained coefficients are grouped together by discarding the zero coefficients in between, a lowpass frequency response with its pass band and transition band widths M times that of the modal filter is obtained[10]. This operation is called as CDM-II.

$$H'\left(e^{j\omega}\right)=\frac{1}{M}\sum_{k=0}^{M-1}H\left(e^{j(\omega-\pi\frac{(2k+1)}{M})}\right) \quad [1]$$

3. Proposed Method

3.1. NPR cosine modulation

Multirate near perfect reconstruction cosine modulation filter bank with non uniform frequency spacing and linear phase property. In cosine modulation , all the filters of analysis and synthesis section are obtained by cosine modulation of sine In this system, the impulse responses of analysis filters h (n) k and synthesis filters f (n) k are the Cosine Modulated versions of a single prototype filter h(n) [2]. Therefore the design of the whole filter bank reduces to that design for the prototype filter. The filter bank has perfect reconstruction if the polyphase components of A reconfigurable transmultiplexer that is capable of on-board demultiplexing of a varying number of single channel per carrier frequency division multiple access (FDMA) channels with varying bit rates is presented. The multiplexing algorithm selected for demultiplexing the FDMA channels is the polyphase FFT (fast Fourier transform) method, which requires a bank of filters followed by an FFT operation. A reconfigurable shared filter bank and reconfigurable pipelined FFT architecture are designed to implement the bank of filters and FFT operations for two different cases[6]. The architecture is suitable for satellite on-board processing as it is reconfigurable and modular and can perform its processing in real time without large buffers. The architecture is illustrated specifically for demultiplexing 800 channels, at 64 kbps or a mix of 400 channels at 64 kbps and 12 channels at 2.048 Mbps or 24 channels at 2.048 Mbps. Fig.1 shows the representation of the channelizer where each complex BPF Hk(ω) has a center frequency of , which corresponds to a particular RF channel. Theoretically, a filter bank channelizer can extract any channel in pithe band (−Fs/2, Fs /2) where Fs is the sampling rate of the channelizer input (output of ADC). This implies that the complexity of a filter bank channelizer remains constant, independent of the number of channels[3]. The impulse responses of the bandpass filters are defined by hk(n) = where h0(n) is a real causal LPF. It follows then that the frequency response of the BPF Hk(ω) can be expressed as the modulated version of H0(ω)

$$X_d(z)=\sum_{k=0}^{M-1}\sum_{M=0}^{M-1}X_M(z)F_M\left(z^{\frac{1}{M}}W_M^k\right)H_d\left(z^{\frac{1}{M}}W_M^k\right) \quad , \quad d=0,1,2,...........,M-1 \quad [2]$$

M-band cosine modulated perfect reconstruction filter bank is created ,

$$[c_1]_{k,l} = 2\cos\left(\frac{\pi}{M}(k+0.5)\left(l-\frac{N}{2}\right)+(-1)^k\frac{\pi}{4}\right) \qquad [3]$$

$$[c_2]_{k,l} = 2\cos\left(\frac{\pi}{M}(k+0.5)\left(2M-1-l-\frac{N}{2}\right)+(-1)^k\frac{\pi}{4}\right) \qquad [4]$$

$$0 \le l \le 2M-1\ , \quad 0 \le k \le M-1$$

The coeffecients of cosine modulated filter bank are represented in eqn.[3] and [4].

During the design phase, only the filter coefficients of prototype filter are required to optimize particularly in case of NPR filterbank.

The theory and design of M-channel Cosine Modulated filter banks [4] have been studied extensively in the past [1]-[3]. The Cosine Modulated filter banks emerged as an attractive choice for filter banks due to its simple implementation and the ability to provide PR. In this system, the impulse responses of analysis filters $h\ (n)\ k$ and synthesis filters $f\ (n)\ k$ are the Cosine Modulated versions of a single prototype filter $h(n)$ [10]. Therefore the design of the whole filter bank reduces to that design for the prototype filter. The filter bank has perfect reconstruction if the polyphase components of the prototype satisfy a pair-wise power complementary condition,

$$\tilde{H}_k(z)H_k(z)+\tilde{H}_{M+k}(z)H_{M+k}(z)=\frac{1}{2M} \qquad [5]$$

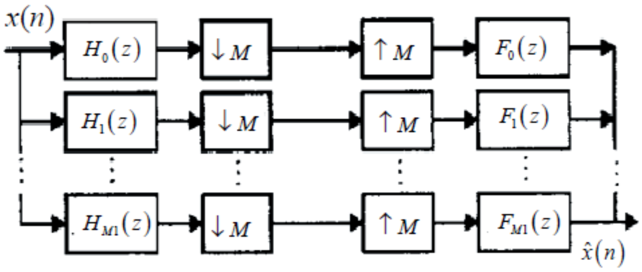

Fig.2 Block Diagram of Cosine Modulated filter bank

The detail design of the prototype filter can be found in [1], where the optimization of the prototype filter coefficients is given. Several efficient methods have been proposed facilitate the design of prototype filter. In [8], Creusere and Mitra proposed a very efficient prototype design method without using nonlinear optimizations. Instead of a full search, it is limited to the class of filters obtained using the Parks-McClellan algorithm. As a result, the optimization can be reduced to that of a single parameter. In the Kaiser Window method of prototype filter design for Cosine Modulated filter banks [9], the design process is reduced to the optimization of the cutoff frequency in the Kaiser Window. Another design method in [10] is based on windowing, which varies the value of 6-dB cutoff frequency of the prototype filter so that final prototype filter has its 3-dB cutoff frequency located approximately at $\pi / 2M$. The structure of the Cosine Modulated polyphase filter bank is shown in [11].

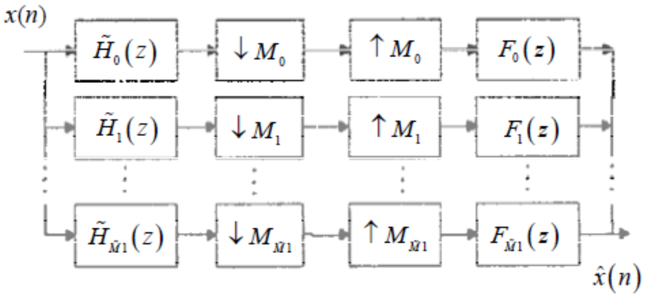

Fig.3 Modified Cosine modulated Filter bank

3.2. Modified Cosine Modulated Filter bank

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In this structure, the input signal x[n] will be decomposed into M polyphase components and the prototype filter will have 2M polyphase components. Each of the polyphase components of the input signal will be filtered with a pair of sub-filters that satisfy the pair-wise power complementary condition as shown in equation [3] and [4].

4. Simulation Results

Perfect reconstruction synthesis filter banks at the transmitter and analysis filter banks at the receiver allow perfect recovery of communication symbols, but the challenges arise with ISI-inducing channels and noise, either of which destroying the perfect reconstruction property. Many practical transceivers do not achieve perfect reconstruction but get close to perfect reconstruction. In order to measure the degree of closeness to perfect reconstruction, we will introduce three traditional quantities to measure sources of distortions: aliasing distortion, magnitude and phase distortions [2]. These distortion measures are based on the blocked model.

The "Plot Frequency Response" subVI accepts filter coefficients either in direct form -- a (reverse) and b (forward) coefficients -- or in cascade form produced by the LabVIEW filter coefficient calculator subVIs and produces the frequency response magnitude and phase plots as well as the group delay plot. Magnitude can be plotted in either linear or dB scale and phase can be plotted as either wrapped or unwrapped.

Polt frequency response is a polymorphic vi a multi function VI either it can be used for Direct form coefficients or for cascade form coefficients. If the inputs are coefficient values we can make use of Direct form coefficients, if the inputs are IIR filter signal we can go for cascade. Ramp Pattern has been used for the normalized frequency, where it is a polymorphic vi with the start and end from -180 to 180 degree. ω [rad/S] is the signal output which is generated from the Ramp pattern which is divided by π for the normalized frequency (w/π) The Signal from the Ramp Pattern has been converted into complex form by using double precision to complex and multiplied with 0-1i. Then the exponential exp(-jw) has been taken out. Then the Polynomial Evaluation has been taken. A and P(x) is the input terminal of Polynomial evaluation vi. It evaluates the Polynomial P(x) with single value or multiple value. The data types connected to A and P(x) determines the polymorphic instance. The A terminal has been connected with exp(-jw) and P(x) has been connected with forward and reverse co efficient respectively.

Both the polynomial equations of forward and reverse has been divided and converted to polar form. The Real values has been plotted as Magnitude along with the normalized frequency. The θ value has been taken out from the polar which is been divided with π to get the Normalized Phase (θ/π).The Magnitude and Phase uniformity can be checked by calculating the magnitude by using the formula $\sqrt{x^2+y^2}$ from x+iy and phase from arctan(y/x). By checking these magnitude and phase as in Fig.3, both would be closer which states the uniformity of the signal.

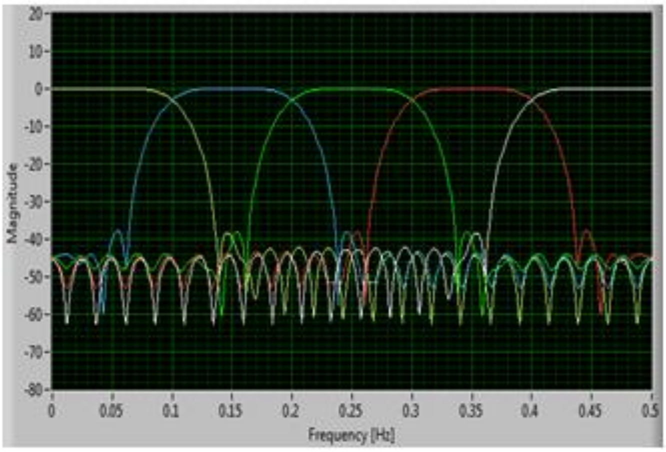

Fig.4 Five channel cosine modulated Filter bank

5. Conclusion

The modified cosine modulated filter bank is developed with near perfect reconstruction technique for the transmultiplexers. Optimizing the filter coefficients to minimize the composite objective function of the stop band attenuation and amplitude distortion .The proposed filter bank technique can extract uniform narrow bandwidths channels compared to conventional Filter banks. The additional optimization methods may be adopted to reduce the complexity to a minimum by reconfiguring the coefficients.

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