



Design of Improved Transmultiplexers for Cognitive Radio Applications

KEYWORDS

Transmultiplexers , Cosine modulation , filter bank , Reconfigurability, Channelization , Multirate FIR filter

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ABSTRACT Transmultiplexers (TMUXs) allow different users to share a common channel to have distinct bandwidths allocated for different applications. The signals are multiplexed together and transmitted in a single channel. Existing designs provide non linear optimization with large no. of coefficients and high degree of complexity. The improved transmultiplexers structure is designed for demultiplexing the FDMA channels of frequency band allocation in cognitive radio applications. This structure must have the capability of extracting multiple channels of distinct bandwidth corresponding to the different communication standards by the cosine modulation filter bank with near perfect reconstruction technique. Design analysis proved that the optimum device utilization is achieved for the filter bank approach in the improved transmultiplexers.

I. Introduction

Cognitive radio (CR) provides a means for efficient utilization of the radio electromagnetic spectrum. Its basic principle is to sense the spectral occupancy over a wide frequency range so as to allow unlicensed users (called secondary users) to have opportunistic access of the vacant frequency bands (spectrum holes) allotted to licensed users (called primary users) [1, 2]. The channelizer used in CRs enables them to have a time-varying adaptability to transmit/receive signals of multiple communication standards in the detected spectrum holes (vacant frequency bands). Multirate Digital signal Processing is used to filter and shift to baseband all the independent information channels. On the transmitter side, complementary processing is carried out. More stringent filtering is required to avoid adjacent channel interference.

Transmultiplexers are used for interconversion between the time-division multiplexing (TDM) and the frequency-division multiplexing (FDM) formats. Their main application is for simultaneous transmission of several data signals through a single channel. Multirate Digital signal Processing is used to filter and shift to baseband all the independent information channels. On the transmitter side, complementary processing is carried out. More stringent filtering is required to avoid adjacent channel interference.

1.FFBR (Flexible frequency band reallocation)

In a dynamic communication system, the bandwidth and centre frequency of the users may change in a time varying manner. The necessities of FFBR networks which can dynamically perform reallocation of users with different bandwidths. Flexibility to handle all FBRs on users with different bandwidths [5], Low complexity to reduce the implementation cost. The amount of improvements in system capacity and implementation cost. Simplicity in system analysis and design. Near perfect frequency band reallocation to satisfy any communication performance metric applications. The digital part of the satellite on-board signal processor is a multi-input multi output system. The input/output signals can have different bandwidths. Such a communication system must support different communication. We need efficient reuse of the limited available frequency spectrum by satellite on-board signal processing. Flexible frequency-band reallocation (FFBR) networks also referred to as frequency multiplexing and demultiplexing the on-board signal processor reallocates all sub bands to different output signals and center frequencies.

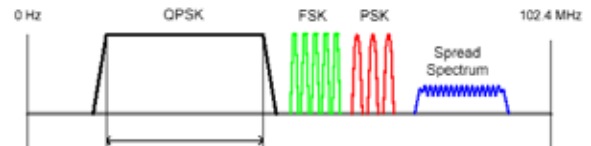


Fig.1 Possible frequency plan

II.Uniform Channelization

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. DFT Modulated Transmultiplexer

Tmux requires adjustable commutators so that any user occupies any portion of the frequency spectrum in uniform complex DFT modulated transmultiplexers. In these filter bank (FB) based structures a synthesis bank performs channel frequency multiplexing at the transmitter side and the analysis bank implements the equivalent channelization in the receiver. This represents a symmetric system design where effects such as amplitude and phase distortion caused in one half of the filter bank and suppressed in the complementary half.

II .Proposed Structure

This method involves the use of modified cosine modulated filter bank in transmultiplexer structure for uniform channelization.

Steps:

1. Create an M-band cosine modulated perfect reconstruction filter bank.
2. Decimate the coefficients for the multirate signal frequency response.
3. Generate a QAM signal as the transmitted signal.
4. Convert the transmitted signal into a frequency multiplexed (FDM) signal has perfect reconstruction if $L+j$ is a multiple of M , where L is the order, j is the delay and M is the band count.
5. Convert the received FDM signal back in to QAM Signal.

1. Channel simulation:

The Gaussian White Noise VI generates the Gaussian-distributed pseudorandom sequence using a modified version of the Box-Muller method to transform uniformly distributed random numbers into Gaussian-distributed random numbers. Lab VIEW uses a triple-seeded very-long-cycle linear congruential generation (LCG) algorithm to generate the uniform pseudorandom numbers.

2. Cosine modulation Filter bank

The Cosine Modulated filter banks emerged as an attractive choice for filter banks due to its simple implementation and the ability to provide Perfect Reconstruction. 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 $h(n)$. Therefore the design of the 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. 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 to facilitate the design of prototype filter. In [8], proposed a very efficient prototype design method without using nonlinear optimizations.

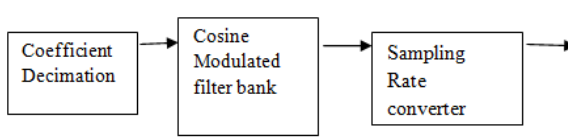


Fig.2 Synthesis Filter

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 .

$$h'(n) = h(n)d_M(n) \quad [1]$$

$$d_M(n) = 1, n = mM, m = 0, 2, 4, 6 \quad [2]$$

$-1, n = pM, p = 1, 3, 5, 7, 0$, otherwise its 3-dB cut off frequency located approximately at $\pi / 2M$.

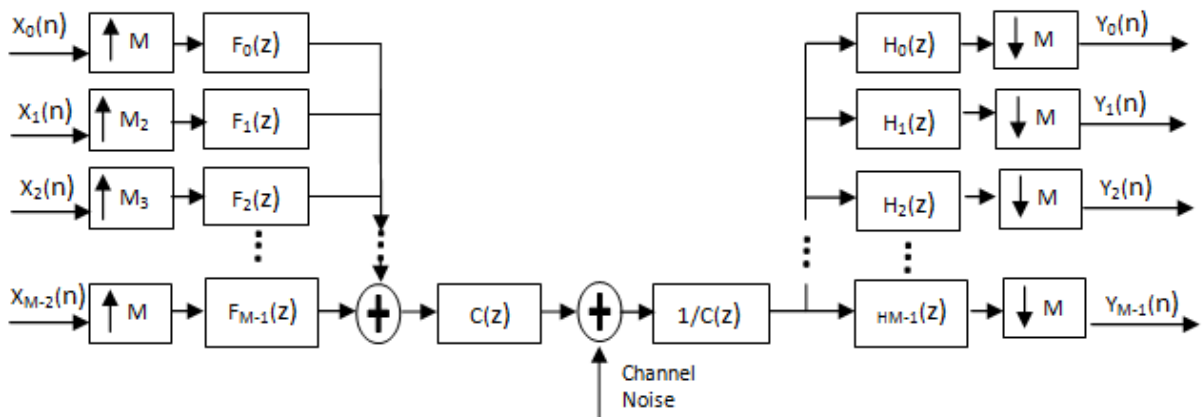


Fig.4 Improved Transmultiplexer structure

3. 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 num-

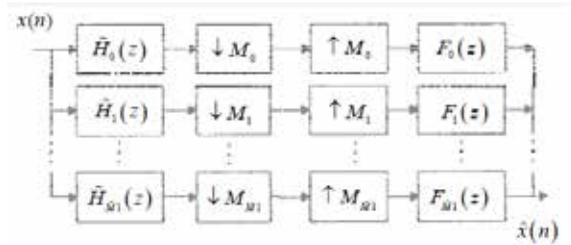


Fig.3 Modified Cosine Modulated filter bank

ber 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. 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

kpbs or a mix of 400 channels at 64 kpbs and 12 channels at 2.048 Mbps or 24 channels at 2.048 Mbps.

Fig.2 shows the representation of the channelizer where each complex BPF $H_k(\omega)$ has a center frequency of ω_k which corresponds to a particular RF channel. Theoretically, a filter bank channelizer can extract any channel in the band $(-F_s/2, F_s/2)$ where F_s 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. The impulse responses of the bandpass filters are defined by $h_k(n) = h_0(n - k)$ where $h_0(n)$ is a real causal LPF. It follows then that the frequency response of the BPF $H_k(\omega)$ can be expressed as the modulated version of $H_0(\omega)$

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

, d=0,1,2,...,M-1

M-band cosine modulated perfect reconstruction filter bank is created, The coefficients of cosine modulated filter bank are represented in eqn.[3] and [4].

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

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

$$0 \leq l \leq 2M - 1, \quad 0 \leq k \leq M - 1 \quad [4]$$

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 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 $h(n)$ and synthesis filters $f(n)$ 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,

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

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 cut-off 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]. The prototype filter will have $2M$ polyphase components. Each of the polyphase components of the input signal the input signal $x[n]$ will be decomposed into M polyphase components and the 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:

Optimization results :

Transmultiplexers with different values of ρ and k attenuation change with different number of channels M . Optimum trade off between rolloff factor ρ and the filter length parameter k to minimize the implementation complexity.

Analysis:

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.

Thus our optimal filter bank-based transceiver design problem using FIR subsystems can be stated as follows : given the FIR channel and desired reconstruction time delay d , design FIR transmitter and receiver subsystems of some given lengths to minimize J subject to some constraint on JN in [10] and the stopband energy constraints on JH_i

Plot Frequency Response

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. Plot 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, 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. w [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.

III.Conclusion and Future work

In this paper ,computationally efficient design of improved transmultiplexer is presented . the proposed method of Transmultiplexers provide the optimized solution. This approach is suitable for the increase in number of sidebands without increase in the order of the filters. To introduce a non-uniform TMUX which have different sampling rates. We can achieve perfect reconstruction as well as efficient frequency band reallocation without aliasing distortion by varying sampling rates and filter coefficients at the receiver (analysis filter bank) .

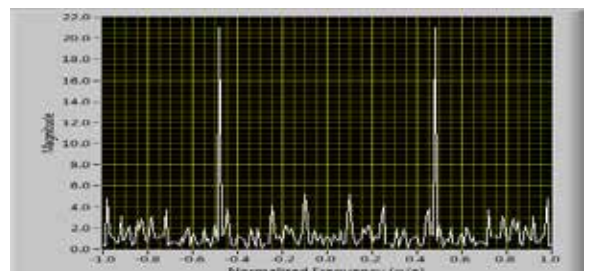


Fig .5 a) Sub band1

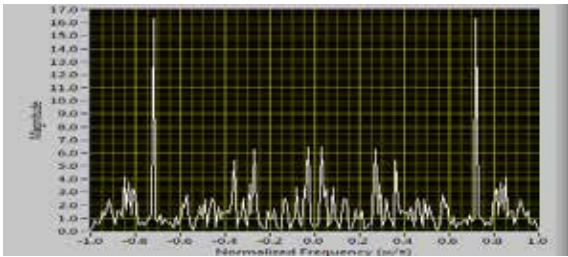
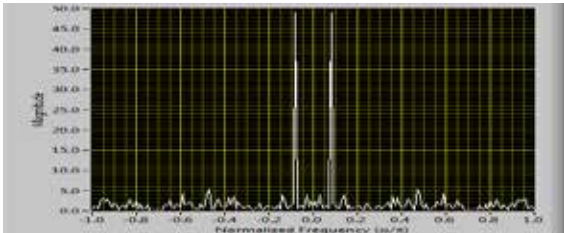


Fig.5 b) Sub band 2



c) Subband 3 , Subbands in Transmultiplexer

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