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Implementing Low Complexity FIR Filter Using IFIR Technique

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***Abstract*— FIR filters are extensively used because of the ease implementation, inherent stability and linear phase. But they have the limitation that their complexity increases as the order of the filter increases. The complexity of linear-phase finite-impulse response (FIR) filters is dominated by the complexity of coefficient multipliers. The number of adders (subtractors) used to implement the multipliers determines the complexity of the FIR filters. Although the complexity of multiplier blocks is significantly reduced by using efficient techniques such as decomposing multiplications into simple operations and sharing common subexpression. In this paper, we present an IFIR technique to minimize the complexity of multiplier blocks. Here the prototype filter is designed using interpolated finite impulse response (IFIR) technique. The stretched factor is chosen in such a way so that computational cost will be reduced. The IFIR approach leads to reduction in stopband energy in magnitude response of the prototype filter. There is a savings in computational complexity and improvement in performance with respect to the previous works. FIR filter design method and the frequency response method were presented but they were improved upon with the IFIR design technique. The results shown that the computational cost of a Interpolated FIR (IFIR) is less with comparing the computational cost of a FIR filter.**

Keywords— **Canonical signed-digit(CSD), Interpolated filtering (IFIR), Finite impulse response filter (FIR).**

I INTRODUCTION

Finite impulse response (FIR) digital filters are frequently used in digital signal processing by virtue of stability and easy implementation. Although programmable filters based on digital signal processing cores can take an advantage of flexibility, they are not suitable for recent consumer applications demanding high throughput and low power consumption. In such an application, therefore, application specific FIR filters are frequently adopted to meet the constraints of performance and power consumption. FIR Filters are used in a wide range of applications, such as speech and image coding, data compression, biomedical signal processing, transmultiplexer design and communications. The complexity of FIR filters in this case is dominated by the number of additions/subtractions used to implement the coefficient multiplications. To reduce the complexity, the coefficients can be restricted to powers-of-two or expressed in canonical signed-digit (CSD) or graph representation to minimize the number of additions/subtractions required in each coefficient multiplication. Early works have focused on replacing multiplications by decomposing them into simple operations such as addition, subtraction and shifting. As the coefficients of an application specific filter are constant, the decomposition is more efficient than employing multipliers. In order to reduce the extra computational complexity that accompanies high filter orders[6], implementations such as the Interpolated Finite Impulse Response (IFIR) method were created. The IFIR technique has been shown to significantly reduce the computational complexity of practical FIR filters. Sampling rate increase and sampling rate reduction are basically interpolation processes and can be efficiently implemented using finite impulse response (FIR) digital filters. The processes of sampling rate reduction (often called decimation) and sampling rate increase (often called interpolation) [3]. In our proposed method, the prototype filter is designed using well-known IFIR technique [1,2] which reduces the overall complexity of the filter bank and performance of the filter is improved greatly with decreased amount of computations.

II. EQUIRIPPLE FIR FILTER & IFIR FILTER

When an equiripple filter is desired, a computer-aided iterative approach is usually employed to reach the specifications within a certain error. The resultant FIR filters of different algorithmic approaches are called equiripple because their minimized weighted error function exhibits an equiripple behavior.

Equiripple IFIR Filter

In it's simplest form, the IFIR design can be thought of as a cascade of two filters. This is depicted in Fig.1 and expressed in equation 1.

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$$H(z)= F(z^L)\, G(z) \qquad (1)$$

F (z) is called the shaping filter because it determines the shape of the resulting filter. F (Z^L) is an upsampled version of this shaping filter. I(z) is known as the imaging filter or interpolator because it reconstructs the sparse impulse response given by F (Z^L) and suppresses the undesired pass band images that result from the up sampling. This technique greatly reduces the number of multipliers needed to meet given specifications[4].

Where

ωp = Pass band edge angular frequency

ωs = Normalized stop band edge angular frequency

$\boldsymbol{\delta} p$ =Peak pass band ripple

δs = Peak stop band ripple

When the IFIR design is used, first an up sampling factor, L, must be found. From [1], the largest value of L is given by

$$L_{max} = \left[\frac{\pi}{\omega s}\right] \qquad (2)$$

Improvement of IFIR[5] Filter design equation given as

$$L_{max} = \left[\frac{2\pi}{\omega p+\omega s+\sqrt{2\pi(\omega s-\omega p)}}\right] \qquad (3)$$

III. Results And Discussions

The disadvantage of Finite Impulse Response (FIR) Filters is that the filter order tends to grow inversely proportional to the transition bandwidth of the filter. In thesis paper, For FIR filter,

Fp = 0.013, Fs = 0.014, δp = 0.001, δs = 0.000

The magnitude response is shown in Fig.2.

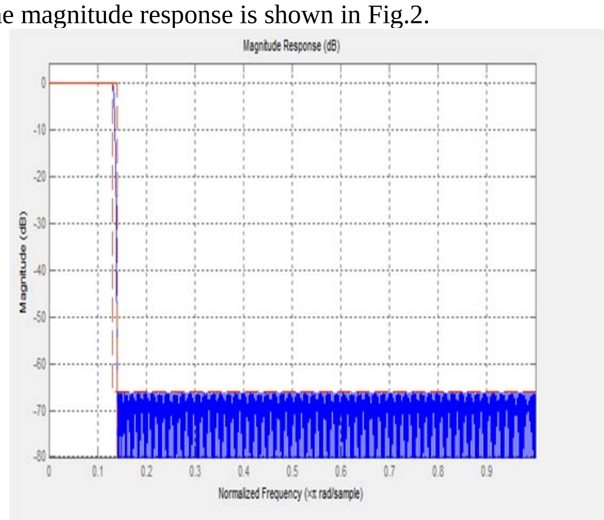

Fig.2 Equiripple FIR Design

The IFIR design algorithm[7] achieves an efficient design for the above specifications in the sense that it reduces the total number of multipliers required. To do this, the design problem is broken into two stages, a filter which is upsampled to achieve the stringent specifications without using many multipliers. The IFIR Filter design is shown in Fig. 3.

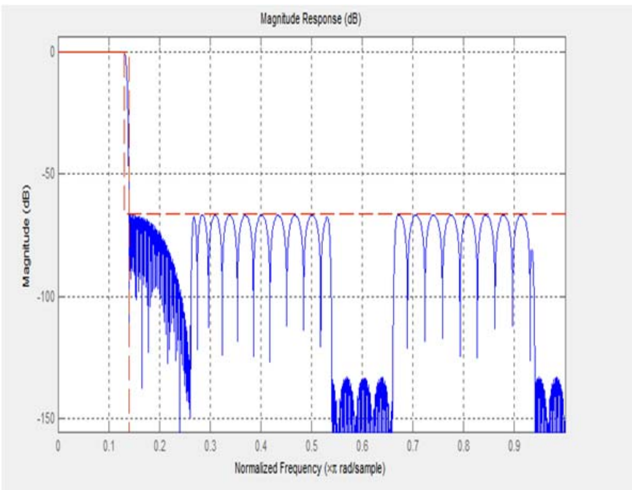

Fig.3. IFIR Design

The IFIR design introduces more delay than the single-stage equiripple design,but less so than the multirate/multistage design but less so than the multirate/multistage design. Then we filtering a Signal the IFIR and multistage/multirate design perform comparably to the single-stage equiripple design while requiring much less computation shown in Fig 4.

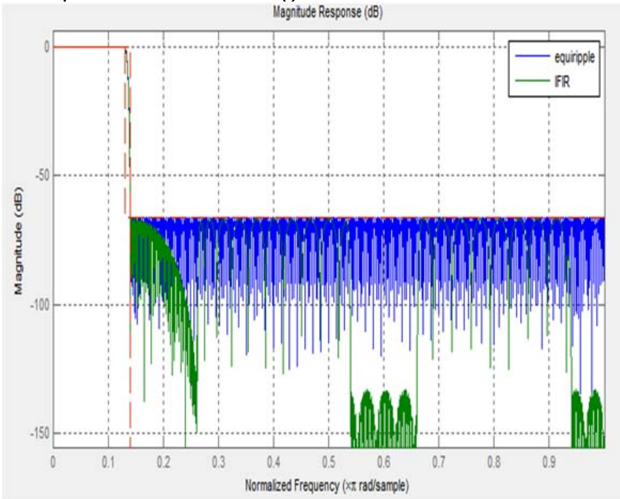

Fig 4.Comparison of Equiripple and IFIR Design

Signal stage FIR filters Length or number of multiplier is 695 as shown as Table 1

```
Command Window
>> Equiripple

ans =

Number of Multipliers            : 695
Number of Adders                 : 694
Number of States                 : 694
Multiplications per Input Sample : 695
Additions per Input Sample       : 694
```

Table 1.Equiripple FIR Design

```
Command Window
>> interpolatedFIR

ans =

Number of Multipliers            : 208
Number of Adders                 : 206
Number of States                 : 802
Multiplications per Input Sample : 208
Additions per Input Sample       : 206
fx >>
```

Table 2.IFIR Design

```
Command Window
>> Equiripple

ans =

Number of Multipliers            : 695
Number of Adders                 : 694
Number of States                 : 694
Multiplications per Input Sample : 695
Additions per Input Sample       : 694
>> interpolatedFIR

ans =

Number of Multipliers            : 208
Number of Adders                 : 206
Number of States                 : 802
Multiplications per Input Sample : 208
Additions per Input Sample       : 206
>>
```

Table 3. Comparison of Table 1 & 2

If we compare Table 1 no of multipliers (695) with Table 2 no of multipliers is only (208). So IFIR design[9] is good as compare with FIR Design.

Serial No.	Implementation cost comparison		
	Technique	**FIR**	**IFIR**
1.	Number.of Multipliers	695	208
2.	Number Of Adders	694	206
3.	Number of states	694	802
4.	Multiplication per input sample	695	208
5.	Additions per input sample	694	206

Table 4. Comparison of FIR & IFIR technique

IV. CONCLUSIONS

In this paper, a new technique for efficient implementation of FIR filter is presented. The main attraction of proposed method is that IFIR technique[8] used with multiplierless masking filter to design the prototype filter, which provides significant savings in computation cost. It is observed that the proposed technique converged very fast in low number of iterations, and can be effectively used for filters with large number of bands. Using this approach the system complexity in terms of number of multipliers reduces greatly but the group delay of the overall prototype filter is increased and that can be reduced with the help of suitable optimization technique. Therefore this method is useful in variety of applications such as audio and image compression.

This paper has investigated many different design techniques for linear-phase finite impulse response FIR filters. FIR filters have much greater computational complexity and large cost than Interpolated (IFIR) filter. We has also compare FIR Filter with IFIR Filter but result shows IFIR filter cost is less as compare to other design.

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