Inspira- Journal of Modern Management & Entrepreneurship (JMME)
ISSN : 2231–167X, Impact Factor: 5.647, Volume 10, No. 03, July, 2020, pp. 97-101

NOTCH AND COMB FILTER DESIGN: ANALYSIS AND REVIEW

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ABSTRACT

This paper represents the review analysis of two types of filters design. In this paper we discuss the designing of notch and comb filters. For discussing the designing of filters we consider the some standard paper which is based on filter design. First we will discuss about filter then we will discuss about types of filter and give the review on different ways of designing of filter.

KEYWORDS: *Notch Filter, Digital Filter, Resistors, Capacitors, Inductors, Analog Filter's, Circuit Design.*

Introduction

A filter is generally a frequency-selective device. Some frequencies are passed through the filter and some frequencies are blocked by filter. The frequencies of signals that are passed through the filter are called pass band frequencies and those frequencies that are stopped by the filter are called stop band frequencies.The filter is also work as a remove the noise component from the signal and passes the remaining signal. Basically, filters are two types. Analog filter is simply to implement and requires few electrical components like resistors, capacitors and inductors while for implementation of digital filter, first we convert the ananlog signal into digital signal by taking a samples value of analog signal then we implement the digital filter with the help of adders, subtracts, delays etc. which are classified under digital logic components. Analog filter's characteristics are fixed by circuit design and component values. If we want to change the filter characteristics than we have to make major modification in circuit while in digital filters do not require the major modification. But in digital filter we remove the noise easily from the signal as compare to analog filter that's why generally we use digital filters.

Notch Filter

Notch filter [1] contains one or more deep notches. It has perfect nulls in its frequency response characteristics. Notch filters are very useful in many applications where the specific frequency components must be eliminated. For example, instrumentation and recording systems require that the power line frequency 60 Hz and its harmonics be eliminated. For creating a null in the frequency response of a filter at a frequency, we simply introduce a pair of complex-conjugate zeros on the unit circle. But in the FIR notch filter notch has a relatively large bandwidth, which means that other frequency components around the desired null are severely attenuated. To reduce the bandwidth of the null we introduce poles in the system function. The effect of poles is to introduce a resonance in the vicinity of the null and thus to reduce the bandwidth of the notch. In addition to reducing the bandwidth of the notch, the introducing of a pole in the vicinity of the null may result in a small ripple in a pass band of the filter due to the resonance created by poles. The effect of ripple can be reduced by introducing poles and/or zeros in the system function of notch filter.

- **Designing Method**
  - **Paper 1**

In designing and analysis of Notch filter **Lee and Tseng** [2] give the design of 2D notch filter using band pass filter and fractional delay filter. For designing of 2D notch filter decompose the filter into the 2D parallel-line filter and straight-line filter. Then, the parallel-line filter is designed by

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band pass filter and the straight-line filter is designed by fractional delay filter. The purpose of this paper is to establish the relation between 2D notch filter and the fractional delay filter such that 2D notch filter can be designed by using well-documented design method of fractional delay filter. This is designing of the 2D notch filter using band pass filter and fractional delay filter. This is the close form design, so it is easy to use.

- **Paper 2**

Another method of designing of notch filter is given by **Tseng and Pei** [3]**.** In this paper they represent the designing of 2D IIR Notch filter and 2D FIR Notch filter. They explain the 2D IIR Notch filter by simple algebraic method which we have discussed in the above paper and 2D FIR Notch filter explain by Lagrange method. FIR filter requires more arithmetic operation than IIR filter during implementation.

Based on this discussion, they design a 2D FIR Notch filter with notch frequency. They used this filter to remove the single sinusoidal interference superimposed on an image. For real-time processing purpose, the 2D notch filter is preferred. In 2D notch filter case, the notch frequency can be chosen exactly the same as the sinusoidal frequency, so there is nearly no information loss and notch filter technique is much more efficient than conventional FFT method in computational complexity.

- **Paper 3**

Another method of designing of Notch filter is given by **Shen et al** [4]**.** In this paper based upon transfer function, they design a digital notch filter to eliminate the 50 Hz noise. The filter was realized by the software implementation in VC++ environment and simulated by MATLAB. After this process power-line interference removes effectively. Its operation was simple and applicable.

According to the principle of transfer function, the FIR notch filter was designed via software procedure in VC++. Through the specified x(n) and the differential equation f the notch filter, the demodulated series y(n) and could be calculated.In this paper, the transfer function H(z) of digital filter can demodulated the frequency components that was integral multiple of 50 Hz. The experiment showed that the 50 Hz notch filter worked properly with stable and reliable performance.

- **Paper 4**

Another design is presented by the **Srisangngam et al** [5]**.** This paper represents the design of symmetrical IIR Notch filter using pole position displacement. It has modified the transfer function equation with the optimum pole positions for the symmetry of pass-band gain and transition-band gain. First, they present the IIR Notch filter design then they present IIR Notch filter proposed design and finally simulates the result.

The magnitude response of propose IIR Notch filter could control the pass-band gain and transition-band gain. Because of distance from zero position of each side are equal. Then, the magnitude response of an IIR Notch filter is symmetry. In conclusion, the proposed method for the design of IIR Notch filter by modifying the pole position can ensure the symmetry of pass-band and transition-band gain at the target level.

- **Discussion**

In paper 1 **Lee and Tseng** give the design of 2D notch filter using band pass filter and fractional delay filter and using simple algebraic method they design a IIR Notch filter. Due to this technique they remove the sinusoidal interferences corrupted on a desired signal and it is closed-form design, so it is easy to use but they explain only for 2D Notch filter not discuss the 3D notch filter design using same method. In paper 2 **Tseng and Pei** presents the designing of 2D IIR Notch filter and 2D FIR Notch filter. They explain the 2D IIR Notch filter by simple algebraic method 2D FIR Notch filter explains by Lagrange method. We observe that FIR filter requires more arithmetic operation than IIR filter during implementation and they also could not explain the 3D notch filter design using same method. In paper 3 **Shen et al** based upon transfer function design a digital notch filter to eliminate the 50 Hz noise. The filter was realized by the software implementation in VC++ environment and simulated by MATLAB. After this process power-line interference removes effectively. Its operation was simple and applicable. In paper 4 **Srisangngam et al** represents the design of symmetrical IIR Notch filter using pole position displacement. Magnitude response of an IIR Notch filter is symmetry and by modifying the pole position can ensure the symmetry of pass-band and transition-band gain at the target level.

- **Comparison Table**

Table 1: Comparison Table of Notch Filter Design

Paper	Approach	Strength	Weakness
Paper 1	Using simple algebraic method design a IIR Notch filter	Remove the sinusoidal interference s corrupted on a desired signal and it is closed-form design, so it is easy to use.	only fixed 2D notch filter not discuss the 3D notch filter design using same method
Paper 2	2D FIR Notch filter explain by Lagrange method.	For real-time processing purpose, the 2D notch filter is preferred and no information loss and notch filter technique is much more efficient than convention al FFT method in computational complexity.	FIR filter requires more arithmetic operation than IIR filter during implementati on and only fixed 2D notch filter not discuss the 3D notch filter design using same method
Paper 3	Based upon transfer function design a digital notch filter to eliminate the 50 Hz noise with the help of software implementation in VC++ environment and simulated by MATLAB	Power-line interference removes effectively. Its operation was simple and applicable.	
Paper 4	Design of symmetric al IIR Notch filter using pole position displacement	Magnitude response of an IIR Notch filter is symmetry and by modifying the pole position can ensure the symmetry of pass-band and transition-band gain at the target level.	

Comb Filter

Comb filter [1] is a type of notch filter in which nulls occurs periodically across the frequency band, hence comb has periodically space teeth. Comb filters are use in a wide range of practical systems such as in the rejection of power-line harmonics, in separation of solar and lunar components from ionospheric measurements of electron concentration.

- **Designing Method**
  - **Paper 1**

For designing of Comb filter Makarov and Odda[6] present a paper. In this paper the second order COMB filter is consist of two conventional COMB filter in cascade. The purpose of this paper is to simulate this type of filter by using delta modulation (DM) technique which gives the realization low cost, simplicity and an efficient result in real time processing. After that the suggested structure has been simulated through an appropriate computer program to achieve the desired frequency response. This structure is based on DM as analog to digital converter (ADC) for continuous input signal.They represent the conventional COMB filter through cascade both transfer function and together with DM are cascade with conventional filter. This is the suggested structure given by them. DM is cascaded with conventional filter's structure in order to convert the analog input signal into uni-bit digital waveform. In this paper, they constructed and designed of second order filter using computer simulation. This design simplifies the structure of this filter using DM as analog to digital converter for input signal. The simulation results are obtained that MSE decrease by increasing clock-frequency and decreasing hysteresis width of DM.

  - **Paper 2**

Another method of designing of COMB filter is given by **J. L. Rasmussen** [7]. One application of the COMB filter is to remove of the fundamental sinusoidal signal and its harmonics from a signal of interest (SOI). In this condition, it is not feasible to use simple IIR or FIR filter to remove these interfering signals without significant degradation of SOI. In this case, we can use the FFT COMB filter to remove these interfering signals but the FFT method has not often used because of its computational complexity. In this paper they present a new formulation of the FFT COMB filter

that eliminates all limitation of the FFT method and provides advantages over the IIR or FIR COMB filter. In earlier method of FFT COMB filter collect the N samples of data, performing an FFT on this data, zeroing every value of the resulting data, and then performing IFFT to obtain the time domain filtered result. The FFT and IFFT both take order multiplications or multiplications for whole process. Due to this process computational complexity increases. There is another problem in FFT COMB filter if we want to extend this method to larger bandwidth. First, we assume that the original FFT frequency resolution must be maintained. Under this constraint, if the SOI bandwidth is increased, both sampling frequency and N need to be increased. Thus, the FFT size has increased. The FFT/IFFT processing time is also increased. For solving the above problem of FFT COMB filter they give the new design of FFT COMB filter. They use the FFT and IFFT matrix multiplication process to simplify the above problems. It observe that if N and M are choose such that N/M is an integer, the product of the IFFT matrix with the FFT matrix with every rows zeroed produces a sparse, multi-diagonal structure.

From this method the total number of multiplications reduces to N/M. Thus, this method of implementation COMB filtering is a factor of more efficient than the FFT method. This simplified method solves some of problems that were identified. First, computation time has been reduced. Second, there is no restriction that a radix 2 value for the size of the FFT must be used. The only restriction is that N/M must be an integer. There is still requirement that all N samples must be collected before the output can be obtained. The time involved might be too large for some Time Division Multiple Access or network systems. It can be implemented as an FIR filter. Now, its computational complexity is reduce so we can use this filter is to remove of the fundamental sinusoidal signal and its harmonics from a SOI.

- **Paper 3**

Another method of designing a COMB filter is given by **Gordana Jovanovic Dolecek**[8]**.** This paper presents the design of the 2 stage COMB based decimation filter with a very low wideband pass band droop and a high stop band attenuation of the overall filter. In this paper they used polyphase decomposition method to stage 1 to avoid the filtering at the high input rate. Then, they applied the compensation filters for both stages and sharpening technique is applied in the 2 stage to the cascade of comb filter and the compensation filter. The comb filter must have a high alias rejection around the zeros of comb filter and a low pass band drop in the pass band in order to avoid the distortion of the decimated signal. However the comb filter has a high pass band droop and low folding band attenuation. So the main goal of this paper is to decrease the pass band droop and keeping good stop band attenuation. In this paper first, they describe two stage structures, then introduce the compensation filter and finally give the proposed filter.

This is the two-stage compensated sharpened COMB based decimator. The important features of the proposed filter are multiplier less structure and the design parameters are practically do not depend on the values of M1 and M2. In the proposed design of the 2 stage COMB based decimation filter wideband pass band droop is very low and stop band attenuation is high of the overall filter.

- **Discussion**

In paper 1 **Makarov and Odda**give the designing of second order COMB filter using delta modulation which gives the realization low cost, simplicity and an efficient result in real time processing. After that the suggested structure has been simulated through an appropriate computer program to achieve the desired frequency response. This structure is based on DM as analog to digital converter (ADC) for continuous input signal. In paper 2 **J. L. Rasmussen** gives the new method of designing a FIR COMB filter. They present a new formulation of the FFT COMB filter that eliminates all limitation of the FFT method and provides advantages over the IIR or FIR COMB filter. They design a COMB filter using FFT and IFFT matrix multiplication process. Due to this technique computational complexity is reduced and there is no restriction that a radix 2 value for the size of the FFT must be used but there is some restriction. N/M must be an integer, there is still requirement that all N samples must be collected before the output can be obtained and the time involved might be too large for some Time Division Multiple Access or network systems. In paper 3 **GordanaJovanovicDolecek**gives the designing of cascade comb filter. Using polyphase technique, compensation filter and sharpening technique they design a cascade comb filter. Due to this technique there are some advantages. We need a multiplier less structure and the design parameters are practically do not depend on the values of *M1* and *M2* but there is a one disadvantage that is number of cascade filters.

- **Comparison Table**

Table 2: Comparison Table of COMB Filter Design

Paper	Approach	Strength	Weakness
Paper 1	simulate second order COMB filter by using delta modulation (DM) technique	low cost, simplicity and an efficient result in real time processing	
Paper 2	Using FFT and IFFT matrix multiplication process to design a COMB filter	Computational complexity is reduced and there is no restriction that a radix 2 value for the size of the FFT must be used.	N/M must be an integer, there is still requiremen t that all N samples must be collected before the output can be obtained and the time involved might be too large for some Time Division Multiple Access or network systems.
Paper 3	Using polyphase technique, compensation filter and sharpening technique to design a cascade comb filter	Multiplier less structure and the design parameters are practically do not depend on the values of 1 *M* and 2 *M*.	Number of cascade filters

Conclusion

Filter can be designed in many ways. In this paper we discussed the Notch filter and Comb filter and gave the designing of filters on the basis of some standard paper which is based on filter design. In Notch filter, we discussed the four papers which is based upon simple algebraic method, largen method, MATLAB and pole-position method. In Comb filter, we discussed the three papers which is based upon delta modulation, matrix multiplication and polyphase technique.

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