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# To Improve the Magnitude Response, Phase Variation and Phase Delay in FIR Filters using GA

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**ABSTRACT**

***In this present work, FIR filter is designed using GA and its comparison is done with Blackman Window, Parks McClellan in MATLAB. The comparisons are done to improve the magnitude response, phase variation and phase delay. The response is studied by keeping values of fixed order, crossover probability and mutation probability. Out of all the three techniques, GA offers a quick, simple and automatic method of designing low pass FIR filters that are very close to optimum in terms of magnitude response, frequency response and in terms of phase variation. FIR filter design using Blackman Window provide good magnitude response but transition bandwidth is very high, large phase deviation and lack of control of critical frequencies $\omega_p$ and $\omega_s$. To overcome this problem, Parks McClellan is used. But, as the order of the filter is increased, this method is not suitable. Therefore, to solve all these problems, GA is used. With the help of GA, the number of operations in design process is reduced and coefficient calculation is easily realized. In this paper, an iterative method to find the optimal solution of optimal FIR filter design has been introduced. It is shown that in optimal FIR filter design, the passband and stop band ripples of response curve depend on the width of transition band.***

**Keywords:** FIR, Parks McClellan Algorithm, Blackman Window, GA.

## 1. INTRODUCTION

Digital filters [1,2] are classified either as Finite duration Unit Pulse Response (FIR) filters or Infinite duration Unit Pulse Response (IIR) filters, depending on the form of unit pulse response of the system. In the FIR system, the impulse response sequence is of finite duration, i.e., it has a finite number of non-zero terms. Digital filters are classified as Recursive and Non-Recursive filters. The response of Recursive or FIR filters depends only upon present and previous input of signal. FIR filters have the following advantages:-

- They can have an exact linear phase.
- They are always stable.
- The design methods are generally linear.
- They can be realized efficiently in hardware.
- The filter start up transients has finite duration.

Digital filters are integral parts of many digital signal processing systems, including control systems, systems for audio and video processing, communication systems and systems for medical applications. Due to the increasing number of applications involving digital signal processing and digital filtering, the variety of requirements that have to be met by digital filters has increased as well.

Consequently, there is a need for flexible techniques that can design digital filters satisfying sophisticated specifications. This paper presents methods for the sequential optimization design of digital filters. The Parks-McClellan algorithm and its variant have been most efficient tools for the minimax design of FIR digital filters [2]. However, these algorithms apply only to the class of linear-phase FIR filters. The group delay introduced by these filters is constant and independent of frequency in the entire baseband. But, it can be quite large. In practice, a variable group delay in stop band is of little concern and by allowing the phase response to be nonlinear in stopbands, FIR filter can be designed with constant group delay with respect to the passbands which is significantly reduced relative to that achieved with filters that have a constant group delay for the entire baseband.

## 2. THE MAGNITUDE AND PHASE RESPONSE OF FIR FILTERS

We know that DTFT of a finite sequence h (n) is given by [3]

$$H(e^{j\omega}) = DTFT[h(n)]$$

$$H(e^{j\omega}) = \sum_{n=0}^{M-1} h(n)e^{-j\omega nT}$$

or

$$H(e^{j\omega}) = \left| H(e^{j\omega}) \right| e^{j\phi\omega}$$

or

Now magnitude and phase response can be expressed as under:

Magnitude response

$$M(\omega) = \left| H(e^{j\omega} \right|$$

Or
$$= \{Re[H(e^{j\omega})]^2 + Im[H(e^{j\omega})]^2\}^{\frac{1}{2}}$$

and phase response

$$\theta(\omega) = \tan^{-1}\left\{\frac{Im\left[H(e^{j\omega})\right]}{Re\left[H(e^{j\omega})\right]}\right\}$$

The phase and group delay is given by

$$\tau_p = -\frac{\theta(\omega)}{\omega}$$

And
$$\tau_g = -\frac{d\theta(\omega)}{d\omega}$$
, respectively

Linear Phase Filters are those filters in which the phase delay and group are constant i.e., independent of frequency [3].

## 3. STABILITY OF FIR FILTERS

FIR filters are inherently stable filters. The difference equation of FIR filter of length M is given as

$$y(n) = \sum_{k=0}^{M+1} b_k.x(n-k)$$

The coefficients 'bk' is related to unit sample as

$$h(n) = \begin{cases} 1, & n = 1 \\ 2, & n = 0,2 \\ 0, & \text{otherwise} \end{cases}$$

Difference equation can be expand as

$$y(n) = b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) + \ldots\ldots + b_{M-1} x(n-M+1)$$

The BIBO stability states that if the system produces bounded output for bounded input, then the system is a stable system [4].

Here, it is observed that the coefficients 'bk' are stable. The output is bounded if the input is bounded. This means that FIR filter produces bounded output for bounded input. Therefore, FIR filters are always stable systems [3].

Consider that a low pass FIR filter is to be designed with the initial conditions described in Table 3.1. The objective is to draw and compare the magnitude response, pole zero response of FIR filter using the Blackman Window, Parks-McClellan and GA.

**Table 3.1** Initial Conditions for Designing a Filter.

| | |
|---|---|
| Filter type | Low Pass |
| Order of filter | 31 |
| No. of sample point | 65 |
| Stop band frequency($\omega$s) | 0.458 |
| Pass band frequency ($\omega$p) | 0.341 |
| Population Number | 100 |
| Generation Number(G) | 30 |
| Crossover Probability(Pc) | 0.6 |
| Mutation Probability(Pm) | 0.01 |

## 4. PARKS-MCCLELLAN ALGORITHM

According to the Professor Douglas Jones of the University of Illinois, the Parks-McClellan Algorithm [5] may be implemented as the following:

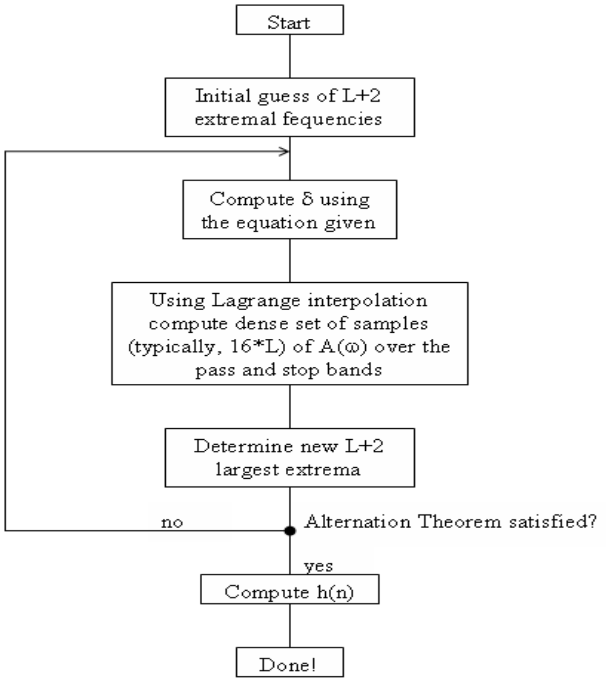


**Figure 4.1** Parks-McClellan Algorithm

To gain a basic understanding of the Parks-McClellan Algorithm mentioned above, we can rewrite the algorithm above in a simpler form as:

Guess the positions of the extrema are evenly spaced in the pass and stop band.

Perform polynomial interpolation and re-estimate positions of the local extrema.

Move extrema to new positions and iterate until the extrema stop shifting.

## 5. OPTIMAL DESIGN OF FIR FILTER USING GENETIC ALGORITHM

The genetic algorithm loops over an iteration process to make the population evolve [6]. It consists of the following steps:

- **SELECTION:** The first step consists in selecting individuals for reproduction. This selection is done randomly with a probability depending on the relative fitness of the individuals, so that best ones are often chosen for reproduction than poor ones.
- **REPRODUCTION:** In the second step, offspring are bred by the selected individuals. For generating new chromosomes, the algorithm can use both recombination and mutation.
- **EVALUATION:** Then the fitness of the new chromosomes is evaluated.
- **REPLACEMENT:** During the last step, individuals from the old population are killed and replaced by the new ones.

The algorithm is stopped when the population converges toward the optimal solution.

The basic genetic algorithm is as follows:

• **Start:** Generate random population of n chromosomes (suitable solutions for the problem)

• **Fitness:** Evaluate the fitness f(x) of each chromosome x in the population

• **New population:** Create a new population by repeating following steps until the new population is complete.

(i) Selection: select two parent chromosomes from a population according to their fitness (The better fitness, the bigger chance to get selected).

(ii) Crossover: With a crossover probability, cross over the parents to form new offspring (children). If no crossover was performed, offspring is the exact copy of parents.

(iii) Mutation: With a mutation probability, mutate new offspring at each locus (position in chromosome)

(iv) Accepting: Place new offspring in the new population.

• **Replace:** Use new generated population for a further sum of the algorithm.

• **Test:** If the end condition is satisfied, stop, and return the best solution in current population.

• **Loop:** Go to step2 for fitness evaluation.

## 6. Simulation Results for Genetic Algorithm

**Filter Coefficient**

**Table 6.1** Filter Coefficients of GA

| Filter Coefficient GA | |
|---|---|
| h(0)= h(31) | - 0.00384 |
| h(1)= h(30) | - 0.00670 |
| h(2)= h(29) | - 0.00108 |
| h(3)= h(28) | 0.01016 |
| h(4)= h(27) | 0.01135 |
| h(5)= h(26) | -0.00586 |
| h(6)= h(25) | -0.02282 |
| h(7)= h(24) | - 0.01063 |
| h(8)= h(23) | 0.02607 |
| h(9)= h(22) | 0.03884 |
| h(10)= h(21) | -0.00797 |
| h(11)= h(20) | -0.07184 |
| h(12)= h(19) | -0.05249 |
| h(13)= h(18) | 0.09853 |
| h(14)= h(17) | 0.29837 |
| h(15)= h(16) | 0.39119 |

**Pole Zeros Plot**

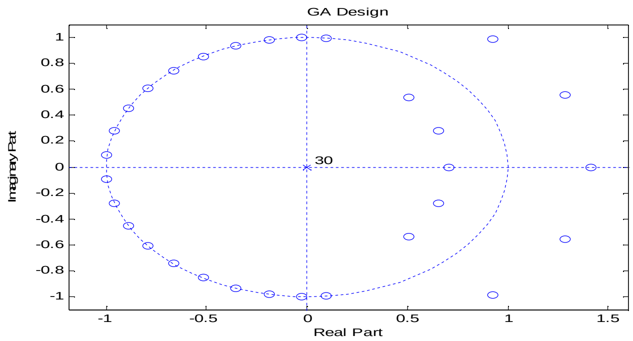


**Figure 6.1** Pole Zeros Plot of GA

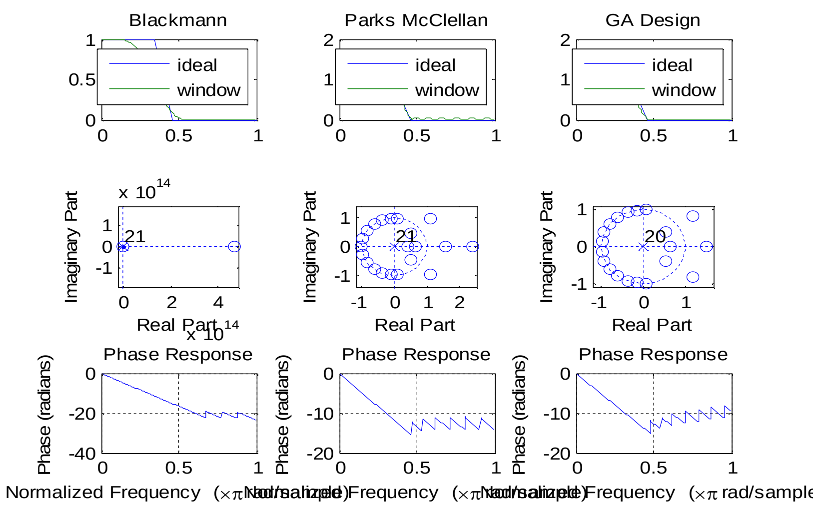


**Figure 6.2** Pole Zeros Plot and phase response of Blackman, parks McClellan and GA

## 7. CONCLUSION

This paper s various optimization techniques for design of low pass FIR digital filters. In this paper, a low pass FIR digital filter has been designed with Parks- McClellan algorithm and GA. The Parks-McClellan algorithm and its variant have been the most efficient tools for the minimax design of FIR digital filters. However, these algorithms apply only to the class of linear-phase FIR filters. The group delay introduced by these filters is constant and independent of frequency in the entire base band but it can be quite large. But, there is a requirement of relatively nonlinear FIR filter. Design examples presented in the paper indicate that the method can be used to design relatively higher order and nonlinear phase FIR filters that are optimal in the minimax sense. In this paper, from pole zero plots, it is observed that the stability in GA is much higher than in the traditional method of optimization (Parks-McClellan algorithm).

## REFERENCES

[1] T. W. Parks and J. H. McClellan, Chebyshev approximation for nonrecursive digital filters with linear phase,"IEEE Trans.Circuit Theory, vol19, pp, 189-194, 1972.
[2] A. Antoniou, Digital Filters: Analysis, Design and Applications, 2nd ed.McGraw Hill, 1993.
[3] Selesnick Ivan W. and C. Sidney Burrus, "Some Exchange Algorithms Complementing the Parks-McClellan Program for Filter Design", Oct 1995.
[4] Rabiner L.R., McClellan J.H., Parks T.W, "FIR Digital Filter Design Techniques using Weighted Chebyshev Approximation", Proceedings of the IEEE, Vol. 63, pp. 595-610, 1975.
[5] Atlanta, Georgia "A Comparison of Different Window Formulation for Two-Dimensional FIR Filter Design", IEEE proceeding- Acoustics, Speech, and Signal Processing , Vol. 4, pp 5-8, Apr 1979.
[6] Y. Kamp and C. J. Wellekens, "Optimal Design Of Minimum Phase FIR Filters," IEEE Trans. Acoustics, Speech, Sig. Proc., Vol. 31, No. 2, pp. 922-926, Aug. 1983.
[7] Rabiner Lawrence R., "Techniques for Designing Finite-Duration Impulse-Response Digital Filters", IEEE Transactions on Communication Technology, Vol. com -19, April 1971
[8] T. W. Parks and J. H. McClellan, "A Program for the Design of Linear Phase Finite Impulse Response Digital Filters," IEEE Trans. Audio Electroacousf, Vol. AU-20, pp. 195-199, 1972.
[9] McClellan James H. and Thomas W. Parks, "A Unified Approach to the Design of Optimum FIR Linear-Phase Digital Filters", IEEE proceeding-circuit theory, Vol. 20, pp. 697 – 701, Nov 1973.
[10] D. Suckley, "Genetic Algorithm in the Design of FIR Filters", IEEE proceeding Circuits, Devices and Systems, Vol. 138, pp. 234-238, Apr 1991.

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