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Analysis of Shadow Filter With Hybrid Windows

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Abstract-- **A new concept of shadow filters are proposed by using hybrid windows which are obtained by combining the different conventional windows (Bartlett, hamming, hanning, Blackman, boxcar etc). The concept of shadow filter is that output of a base filter is giving to the input of another filter which is called feedback filter through feedback constant and the output of feedback filter is again given as input to main filter. By adjusting the value of feedback constant we can get response of main filter. We have to find the value of feedback constant for which the main filter response is good in terms of relative side lobe attenuation and bandwidth and which are compared with the filter without shadow mechanism. In this project LPF acts as the base filter and is tested with all other filters such as LPF, HPF, BRF and BPF in feedback path. Similarly this method is applied to HPF, BRF, and BPF as base filter. The base filter and feedback filters are being taken FIR filters applied with new hybrid windows. Finally shadow filters with conventional windows are compared with shadow filters with new hybrid windows in terms of RSA and BW.**

Index terms—**FIR filter, Hybrid windows, RSA, Shadow filter.**

I. INTRODUCTION

A filter is linear time invariant system [1-3], used for removing undesirable noise from desired signal. It can be used in spectral shaping such as equalization of communication channels, signal detection in radar, sonar etc. A filter is designed to pass a band of desired frequencies without any distortion called pass band of the filter and to totally block a band of unwanted frequencies called stop band of the filter. The digital filters are available as low pass filters, high pass filters, band pass filters and band reject filters. A low pass filter blocks all frequencies above the specified cut off frequency similarly high pass filter passes all frequencies above the specified cut off frequency. Theband pass filter allows a particular band of frequencies and the band reject filter rejects the particular band of frequencies and allows the other frequencies.

Consider a basic second order filter, which is capable of realizing any of the four possible characteristics viz. low-pass, high-pass, band-pass or band reject or a combination of these. Here we take FIR filters for implementation of shadow mechanism using hybrid windows. Hybrid window is a new concept which is obtained by the combination of two different windows. We take the combinations of boxcar, hamming, hanning, bartlett windows. The shadow mechanism is to analyze and compare the frequency responses of Low pass, High pass, Band pass and Band reject filters for different feedback configurations with filters without shadow mechanism.

The characteristics of FIR filters, the windowing technique and the required equations for the hybrid windows are explained.The shadow mechanism concept was also explained in next chapters. We used MATLAB tool for implementation of the filters.

The frequency responses of different filters without shadow mechanism and with shadow mechanism are shown further. Tabular forms of the filters showing the data of Relative side lobe attenuation, main lobe width for different values of β are also given.

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II. FIR FILTERS

Impulse response of digital filters are computed for finite number of samples and hence called Finite Impulse Response filters. The transfer function is given by:

$H(n) \neq 0, \ 0 \leq n \leq M-1$

$= 0, \quad$ elsewhere $\qquad (1)$

These filters are characterized by the system function which is not rational

$$H(Z) = \sum_{K=0}^{M-1} B_K Z^{-K} \qquad (2)$$

A. *Coefficients of linear phase filter*:

Low pass filter with cut off frequency Ω_c

$$h_d(0) = \frac{\Omega_c}{\pi} \text{ for } n = \alpha$$

$$= \frac{\sin \Omega_c (n-\alpha)}{\pi (n-\alpha)} \text{ for } n \neq \alpha \qquad (3)$$

High pass filter with cut off frequency Ω_c

$$h_d(n) = 1 - \frac{\Omega_c}{\pi} \text{ for } n = \alpha$$

$$= \frac{1}{\pi(n-\alpha)}[\sin(n-\alpha)\pi - \sin(n-\alpha)\Omega_c] \text{ for } n \neq \alpha \qquad (4)$$

Band Reject filter with cut off frequency Ω_{c1}, Ω_{c2}

$$h_d(n) = 1 - \frac{\Omega_{c2} - \Omega_{c1}}{\pi} \quad \text{for } n = \alpha$$

$=\frac{1}{\pi(n-\alpha)}[\sin(\pi(n-\alpha)) - \sin\Omega_{c2}(n-\alpha) + \sin\Omega_{c1}(n-\alpha)]$ for $n \neq \alpha$ (5)

Band pass filter with cut off frequency Ω_{c1}, Ω_{c2}

$h_d(n) = \frac{\Omega_2 - \Omega_1}{\pi}$ for n = α

$=\frac{1}{\pi(n-\alpha)}[\sin\Omega_{c2}(n-\alpha) - \sin\Omega_{c1}(n-\alpha)]$

$for\ n \neq \alpha$ (6)

III. TYPES OF WINDOW FUNCTIONS

In signal processing, a window function (also known as an apodization function or tapering function) is a mathematical function that is zero-valued outside of some chosen interval. For instance, a function that is constant inside the interval and zero elsewhere is called a rectangular window, which describes the shape of its graphical representation. When another function or a signal (data) is multiplied by a window function, the product is also zero-valued outside the interval: all that is left is the part where they overlap; the "view through the window".

The following comes under the classification of the windows

- Rectangular window
- Triangular window
- Hanning window
- Hamming window
- Blackmann window
- Kaiser window

A. *Hybrid Windows*:

The hybrid window is a type of window formed by the combination of two different types of windows. The combining of the windows may be done by an operation like arithmetic operations. We take addition of two windows by multiplying a constant 'k'with each window.

The windows which are taken are Boxcar window and Hanning window and constant as 0.5

If wh is the function of Hybrid window, and 'k' is the constant then the equqtions can be written as (7) & (8).

Wn=k*Boxcar(n)+(1-k)*Hanning(n) (7)

or

Wn=k*Hanning(n)+(1-k)*Boxcar(n) (8)

If K=0.5

Wn=0.5*Boxcar(n)+0.5*Hanning(n) (9)

The hybrid window technique is used for improvisation of the signal response of the filter. If we consider only Boxcar window, a lot of Ripples and noise are added to the signal.But by using this hybrid windows, the ripples are decreasedand the stop band attenuation increased without changing the other parameters, and the accuracy increases.

IV. SHADOW MECHANISM

The concept of shadow filter is that output of a base filter is given as input to another filter which is in feedback section called feedback filter and again the output of feedback filter is given as input to base filter. By adjusting the value of numerical constant β we can get response of the filter. The block diagram of the mechanism is shown in following figure (1).

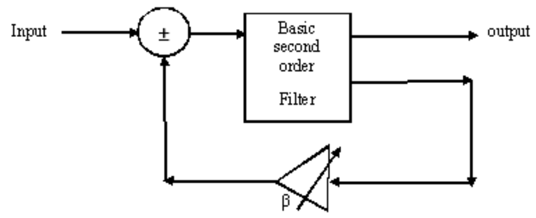

Fig 1: Block diagram for shadow mechanism

The basic second order filter is capable of realizing any of the filters. We have to find the value of numeric constant β for which the filter response is better in terms of relative side lobe attenuation and bandwidth compared to the filter without shadow mechanism. In this paper LPF acts as the base filter and is tested with all other filters such as LPF, HPF, BRF and BPF in feedback path. Similarly this method is applied to HPF, BRF, and BPF as base filter. The base filter and feedback filters are being taken FIR filters applied with new hybrid windows.

V. RESULTS AND DISCUSSION

Results are generated for all filters (LPF, HPF, BPF, BRF) using shadow mechanism with hybrid windows and applying different numerical (feedback) constants.

Table 1.Response of filters Without shadow mechanism.

Type of filter	RSLA	MLW
Low pass filter	-21.60897	0.96094
High pass filter	-21.6294291	1.9922
Band reject filter	-21.3382509	1.9922
Band pass filter	-21.3426121	1.9922

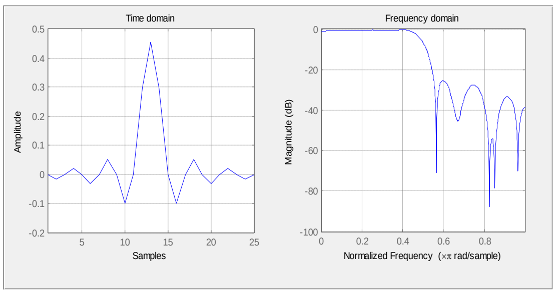

Fig 2. Responses of LPF with feedback LPF

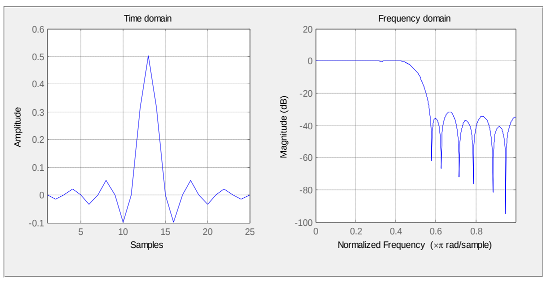

Fig 3. Responses of LPF with feedback HPF

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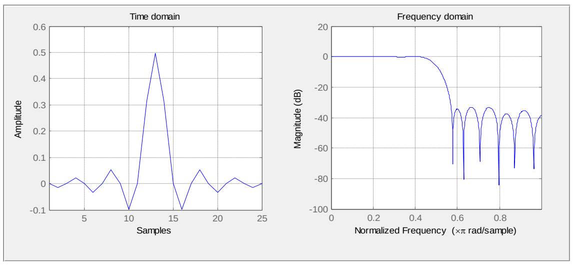

Fig 4. Responses of LPF with feedback BRF

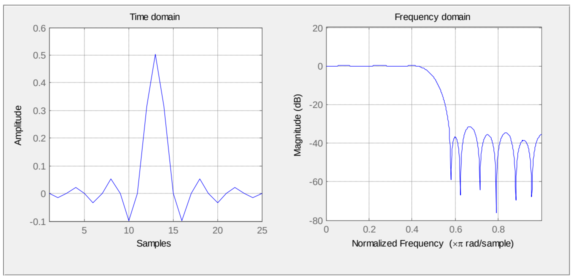

Fig 5. Responses of LPF with feedback BPF

Table 2. Responses of LPF with shadow mechanism for different numerical constant (β) values.

Low pass filter with different feedback filters	Numerical constant	RSLA	MLW
LPF with feedback LPF	0.01	-32.58189	0.95313
	-0.01	-32.84274	0.95313
LPF with feedback HPF	0.01	-31.820785	0.95313
	-0.01	-33.0730	0.95313
LPF with feedback BRF	0.01	-31.623215	0.95313
	-0.01	-33.12427	0.95313
LPF with feedback BPF	0.01	-31.506202	0.95313
	-0.01	-33.105645	0.95313

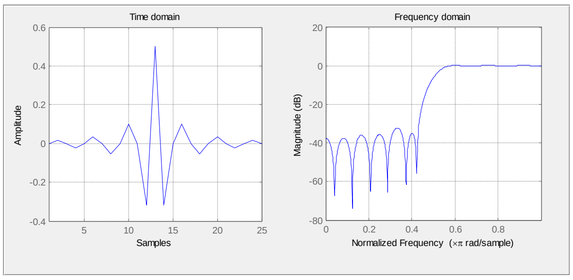

Fig 6. Responses of HPF with feedback LPF

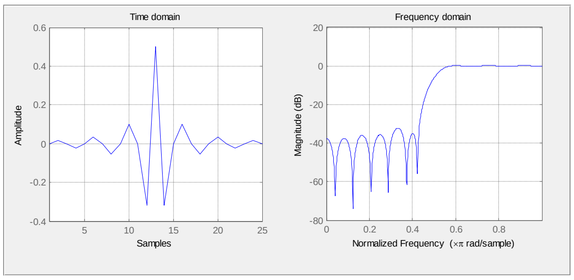

Fig 7. Responses of HPF with feedback HPF

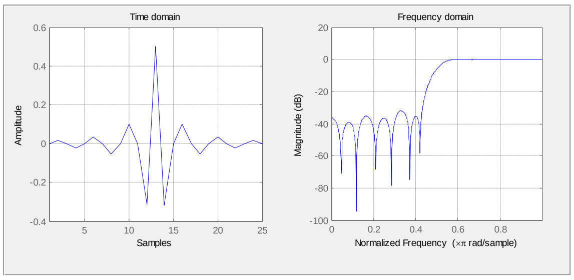

Fig 8. Responses of HPF with feedback BRF

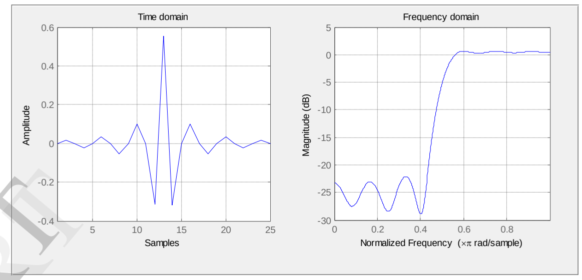

Fig 9. Responses of HPF with feedback BPF

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Table 3. Responses of HPF with shadow mechanism for different numerical constant (β) values

High pass filter with different feedback filters	Numerical constant	RSLA	MLW
HPF with feedback LPF	0.01	-32.829777	1.9922
	-0.01	-33.58795	1.9922
HPF with feedback HPF	0.01	-31.2340	1.9922
	-0.01	-32.986008	1.9922
HPF with feedback BRF	0.01	-32.1453558	1.9922
	-0.01	-33.115566	1.9922
HPF with feedback BPF	0.01	-32.1162682	1.9922
	-0.01	-33.2011589	1.9922

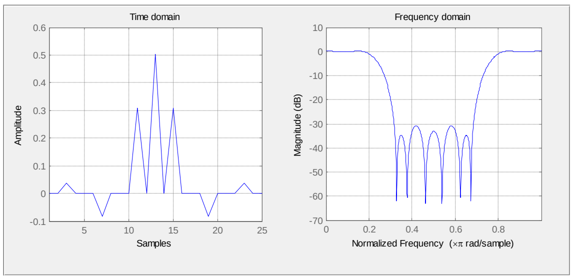

Fig 10. Responses of BRF with feedback LPF

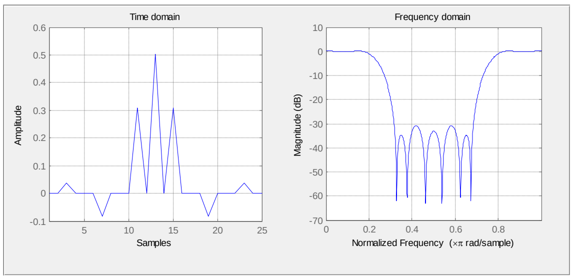

Fig 11. Responses of BRF with feedback HPF

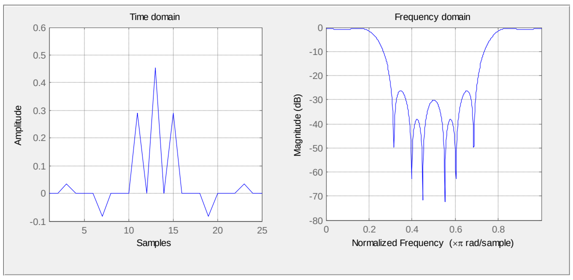

Fig 12. Responses of BRF with feedback BRF

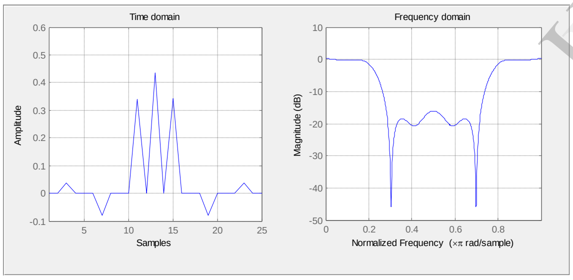

Fig 13. Responses of BRF with feedback BPF

Table 4. Responses of BRF with shadow mechanism for different numerical constant (β) values.

Band reject filter with different feedback filters	Numerical constant	RSLA	MLW
BRF with feedback LPF	0.01	-30.677184	1.9922
	-0.01	-33.146347	1.9922
BRF with feedback HPF	-0.01	-31.5048829	1.9922
	-0.1	-27.0339084	1.9922
BRF with feedback BRF	-0.01	-31.5048829	1.9922
	-0.1	-27.0339084	1.9922
BRF with feedback BPF	0.01	-30.445115	1.9922
	-0.01	-30.868257	1.9922

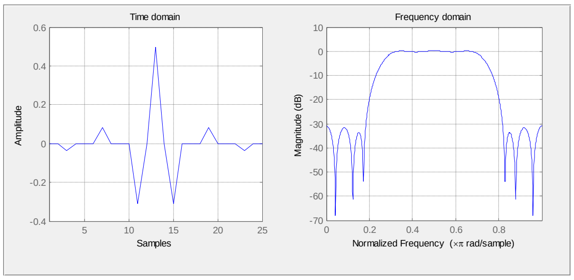

Fig 14. Responses of BPF with feedback LPF

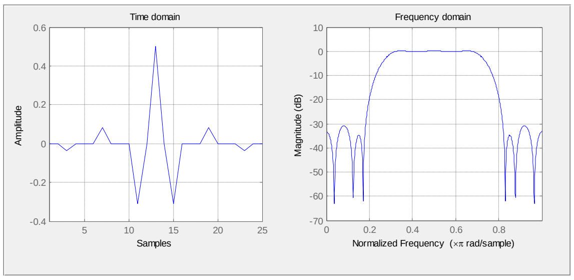

Fig 15. Responses of BPF with feedback HPF

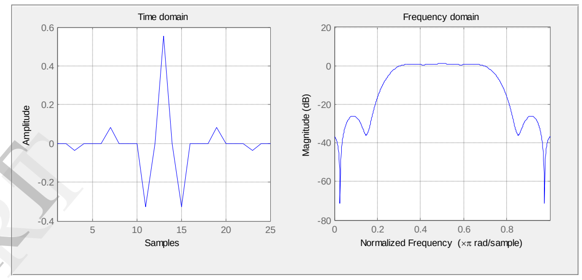

Fig 16. Responses of BPF with feedback BRF

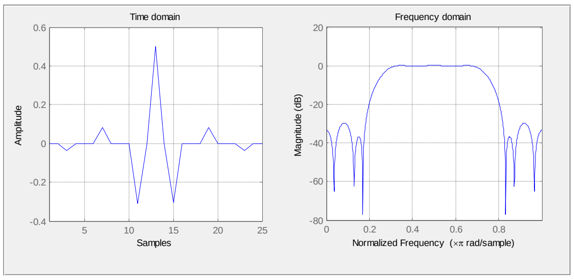

Fig 17. Responses of BPF with feedback BPF

Table 5. Responses of BPF with shadow mechanism for different numerical constant (β) values.

Band pass filter with different feedback filters	Numerical constant	RSLA	MLW
BPF with feedback LPF	0.01	-30.277925	1.9922
	-0.01	-31.806377	1.9922
BPF with feedback HPF	0.01	-30.954613	1.9922
	-0.01	-32.635812	1.9922
BPF with feedback BRF	0.01	-30.794920	1.9922
	-0.01	-31.231530	1.9922
BPF with feedback BPF	0.01	-29.504998	1.9922
	-0.01	-30.381463	1.9922

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VI. CONCLUSION AND FUTURE SCOPE

The versatility of an interesting shadow filter, which can be electronically tuned by varying the gain of an amplifier, has been discussed in this paper. The advantages of shadow filters are same as filters but with better quality and can be quickly understandable for experimentation.

The FIR filters are implemented using FIR with Hybrid windows, so that the ripples in the window can be decreased and attenuation of the stop band also increased. The relative side lobe attenuation has improved a lot using this concept. The input can be any real time signal and this concept can be applied for medical purpose that is for ECG because medical apparatus need accurate signals.

It is observed from the Results and Tabular forms (1 to 5), the relative side lobe attenuation (RSA) has improved for all types of filters with shadow mechanism without altering the main lobe width (MLW) of filters, comparing with the filters without shadow mechanism. The extension for this paper can be done by new window types.

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