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Comparison and Performance Evaluation of Low Pass Filter Design for various samples using Artificial Neural Network

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Abstract- To design any type of filters complex calculation is needed. But with the help of window method, it become simple. In this paper a Low pass filter is designed by window method with the help of Artificial Neural Network. Here, Hann window and Blackman window is used to design filter and Feed Forward Back Propagation algorithm has been taken for neural network. In this paper different data sets for cut off frequency are consider for training and testing purpose to get best results.

Keywords- Blackman Window, FDA Tool, FFBP Network, Hann Window and NN Tool.

1. INTRODUCTION

Digital filters perform signal processing functions, specifically to remove unwanted frequency components from signal, to increase the signal quality and strength. Digital filters are classified either as finite duration impulse response function (FIR) or infinite duration impulse response function (IIR), depending on the form of unit impulse response of the system. Filters can have a linear and non linear phase which depends on delay function. FIR filters have some advantages over IIR filter like FIR filters are stable, their designing methods are generally linear, can also be realized efficiently in hardware and they can also have exact linear phase.

Window functions which are used in this paper are Hann window and Blackman window:

1.1 Hann Window- Hann window is mostly used to reduce the unwanted components on frequency characteristics by which signals can be filtered out at the output side. Filters have higher stop band attenuation if it is designed by Hann window in comparative to triangular window. Filter coefficients can be calculated by using this expression [12]:

$$W[n] = \frac{1}{2}\left[1 - \cos\left(\frac{2\pi n}{N-1}\right)\right]; 0 \le n \le N-1 \;\ldots\ldots (1)$$

1.2 Blackman Window: Beside Kaiser and Hamming window, Blackman window is also considered as the most commonly used window to design a filter. Its high attenuation makes it more convenient for many applications. The minimum stop band attenuation of a filter which is designed by Blackman window is 75 db. Filter coefficients can be calculated by using this expression [12]:

$$w[n] = 0.42 - 0.5\cos\left\{\frac{2\pi n}{N-1}\right\} + 0.08\cos\left\{\frac{4\pi n}{N-1}\right\} \quad ; 0 \le n \le N-1 \quad \ldots\ldots (2)$$

2. ARTIFICIAL NEURAL NETWORK

It is an electronic model which is based on the neural structure of the brain. This biological network gives methods for computing that will be the next major advancement for computing industry. Main processing element of a neural network is a Neuron. It is made up of interconnected neurons which are capable to understand machine language as well as pattern recognition. Number of nodes, their formation and the desired weights of the connections of neural network found the output of the neural network. The system adjusts the weights for the internal connections to reduce the errors between network output and target output. Hidden layers can also increase or decrease according to need. In the engineering tool box, artificial neural network is the latest technology which serves many functions like pattern classifier, to find unknown parameters, identification of speech, image deciphering of scenes, forecasting, also as non linear adaptive filters and many more. Some of these applications need to turn real world input into the discrete functions. The basic diagram of artificial neural network is shown in Figure 1. [10].

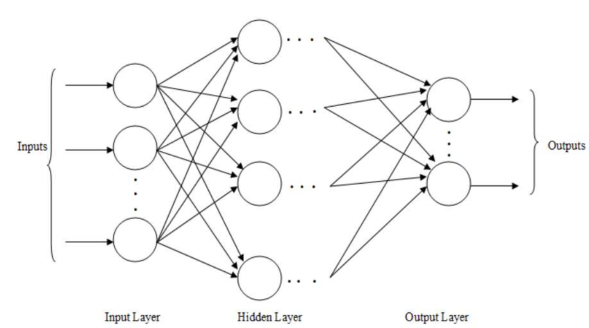

Figure 1. Structure of Neural Network

There are many types of algorithms comes under an artificial neural network like Radial basis function, generalized regression, feed forward time delay distribution network etc. For this paper I have choose feed forward back propagation network.

2.1 Feed Forward Back Propagation

It is a first and the simplest type of neural network. In this network information travel in only one direction like it will send signals in forward direction and errors will move in backward direction. The information moves through the input nodes then it will go to the hidden layers and at last to the output nodes. Hidden layers can be one or more than one, according to our need. The main function of this algorithm is to reduce error. We have to adjust the weights during training so that we can achieve minimum error. Feed forward back propagation network is shown in Figure2. [10].

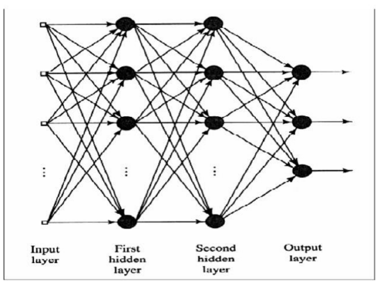

Figure 2. Feed Forward back propagation network

3. METHODOLOGY

In this paper, various data sets for frequency samples are taken to design a low pass filter. For designing a low pass filter, Matlab software is used in which FDA tool and Nn tool are used. To design a Filter with the help of artificial neural network, training, validation and testing samples are required. So different sets for training and testing samples of frequency are taken in this paper to get the best and accurate results.

We have taken 50 samples to design a filter in which some samples are consider as training inputs while other are for testing. Three cases are made for the simulation and all are described below:

3.1 Case 1: In this case out of 50 samples, 37 is used for training purpose while 13 are used for testing purpose. From table 1 result from NN tool for Feed forward back propagation network and the cut off frequency choose for testing purpose can be compared with the help of mean square error for both Hann and Blackman windows.

Table 1. Results and comparison of Hann and Blackman window with 13 test samples

Frequency samples for Testing	**Cut off Frequency of Hann & Blackman window**	**FFBP Algorithm Result From NN Tool**		**Mean Square Error**	
		Hann window	**Blackman window**	**Hann Window**	**Blackman window**
h(0)	0.05	0.028193	0.037	0.0004755452	0.000169
h(1)	0.13	0.13458	0.13297	0.000020976	0.0000088209
h(2)	0.21	0.21003	0.21092	0.0000000009	0.0000000846
h(3)	0.29	0.29016	0.2901	0.0000000256	0.00000001
h(4)	0.35	0.34986	0.34707	0.0000000196	0.0000085849
h(5)	0.43	0.42963	0.4299	0.0000001369	0.00000001
h(6)	0.49	0.49223	0.49093	0.0000049729	0.0000008649
h(7)	0.57	0.54871	0.56962	0.0004532641	0.0000001444
h(8)	0.65	0.63825	0.65	0.0001380625	0.00
h(9)	0.73	0.75087	0.73026	0.0004355569	0.0000000676
h(10)	0.81	0.80999	0.80899	0.0000000001	0.0000010201
h(11)	0.89	0.99	0.8893	0.01	0.00000049
h(12)	0.95	0.99	0.95	0.0016	0.00

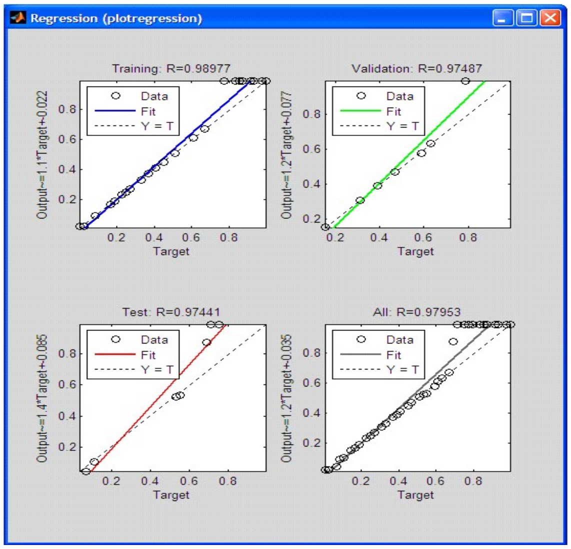

Figure 3. Regression plot for Hann Window

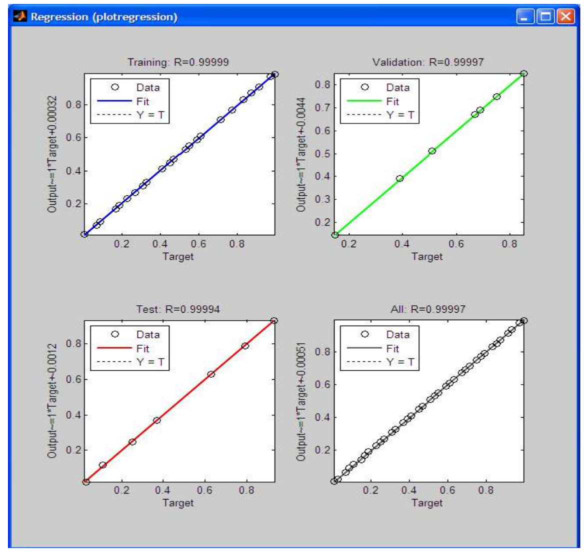

Figure 4. Regression plot for Blackman window

From Figure 3 and 4 regression plot for Hann and Blackman window are seen in which, plot for hann window is not up to the mark, error are showing in figure 3 but error graph for Blackman window is shown negligible error it means training is done properly that's why results are very near to cut off frequency. So it is concluded that Blackman window gives better result in this case.

3.2 Case 2: In this case out of 50 samples, 30 samples are used for training purpose and remaining 20 are used for testing purpose. From table 2 results from NN tool for Feed forward Back Propagation algorithm can be seen and mean square error for both windows is calculated to get better results.

Table2. Results of Hann and Blackman window with 20 test samples

Frequency samples for Testing	**Cut off Frequency of Hann & Blackman window**	**FFBP Algorithm Result From NN Tool**		**Mean Square Error**	
		Hann Window	**Blackman window**	**Hann Window**	**Blackman window**
h(0)	0.01	0.043926	0.03348	0.001150973	0.0005513104
h(1)	0.05	0.047418	0.03908	0.000000666672	0.0001192464
h(2)	0.11	0.073947	0.1606	0.001299819	0.00256036
h(3)	0.15	0.12393	0.1909	0.0006796449	0.00167281
h(4)	0.21	0.20968	0.19706	0.0000001024	0.000166926
h(5)	0.27	0.26578	0.27636	0.0000017808	0.0000404496
h(6)	0.31	0.30224	0.31231	0.0000602176	0.0000053361
h(7)	0.35	0.34082	0.34915	0.00008427	0.00000072
h(8)	0.39	0.38013	0.38874	0.0000974169	0.0000015876
h(9)	0.45	0.43735	0.44974	0.0001600225	0.0000000676
h(10)	0.49	0.47333	0.48962	0.0002778889	0.0000001444
h(11)	0.55	0.53253	0.55029	0.0003052009	0.0000000841
h(12)	0.59	0.57524	0.58858	0.0002178576	0.0000020164
h(13)	0.63	0.61848	0.62637	0.0001327104	0.0000131769
h(14)	0.69	0.68363	0.68436	0.0000405769	0.0000318096
h(15)	0.75	0.7438	0.74296	0.00003844	0.0000495616
h(16)	0.81	0.80774	0.80568	0.0000051076	0.0000186624
h(17)	0.85	0.84902	0.84594	0.0000008604	0.0000164836
h(18)	0.91	0.89761	0.9122	0.0001535121	0.00000484
h(19)	0.95	0.93284	0.95621	0.0002944656	0.0000385641

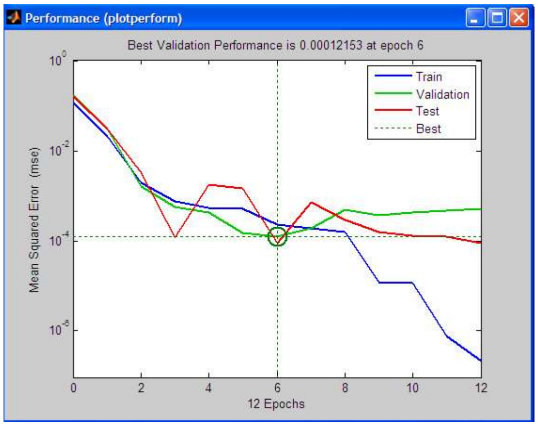

Figure 5. Performance plot of Hann Window

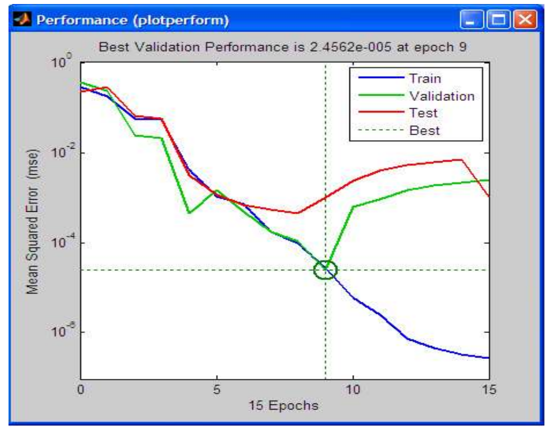

Figure 6. Performance plot of Blackman window

Figure 5 and 6 are showing performance plot for Hann and Blackman window. It is concluded that performance plot that is training graph is better for Blackman window because the graph line for training goes downward and test and validation graph line is almost in the same way so these aspects of this graph shows that network trained well. But in case of Hann window, training graph line is also goes downward that is good but test and validation graph line is not so linear that is why it is not trained properly as compared to Blackman window. So Blackman gives better results.

3.3 Case 3: In this case out of 50 samples, half samples i.e. 25 samples are taken as training purpose and remaining 25 are used for testing purpose. From Table 3 results from NN tool for Feed forward Back Propagation algorithm can be seen and MSE for both windows are calculated to get better results.

Table 3. Results of Hann and Blackman window with 25 test samples.

Frequency samples for Testing	Cut off Frequency of Hann & Blackman window	FFBP Algorithm Result From NN Tool		Mean Square Error	
		Hann Window	Blackman window	Hann Window	Blackman window
h(0)	0.03	0.028663	0.026949	0.000001787569	0.000009308601
h(1)	0.07	0.054198	0.066117	0.0002497032	0.00001507769
h(2)	0.11	0.10864	0.11279	0.0000018496	0.0000077841
h(3)	0.15	0.15458	0.14755	0.0000209764	0.0000060025
h(4)	0.19	0.18845	0.18814	0.0000024025	0.0000034596
h(5)	0.23	0.22904	0.23066	0.0000009216	0.0000004356
h(6)	0.27	0.27433	0.27073	0.0000187489	0.0000005329
h(7)	0.31	0.32777	0.31063	0.0003157729	0.0000003969
h(8)	0.35	0.37434	0.35048	0.0005924356	0.0000002304
h(9)	0.39	0.39885	0.39223	0.0000783225	0.0000049729
h(10)	0.43	0.42888	0.43327	0.0000012544	0.0000106929
h(11)	0.47	0.47247	0.46535	0.0000061009	0.0000216225
h(12)	0.51	0.50823	0.49999	0.0000031329	0.0001002001
h(13)	0.55	0.54998	0.53837	0.0000000025	0.0001352569
h(14)	0.59	0.587	0.600061	0.000009	0.0001012237
h(15)	0.63	0.62314	0.65667	0.0000470596	0.0007112889
h(16)	0.67	0.68202	0.69598	0.0001444804	0.0006749604
h(17)	0.71	0.72621	0.7205	0.0002627641	0.00011025
h(18)	0.75	0.72778	0.73799	0.0004937284	0.0001442401
h(19)	0.79	0.74703	0.75679	0.01846421	0.001102904
h(20)	0.83	0.79357	0.78618	0.001327145	0.001920192
h(21)	0.87	0.83608	0.84772	0.001150566	0.0004963984
h(22)	0.91	0.86096	0.87124	0.002404922	0.0001502338
h(23)	0.95	0.87351	0.90592	0.00585072	0.001943046
h(24)	0.99	0.86861	0.92903	0.01473553	0.003717341

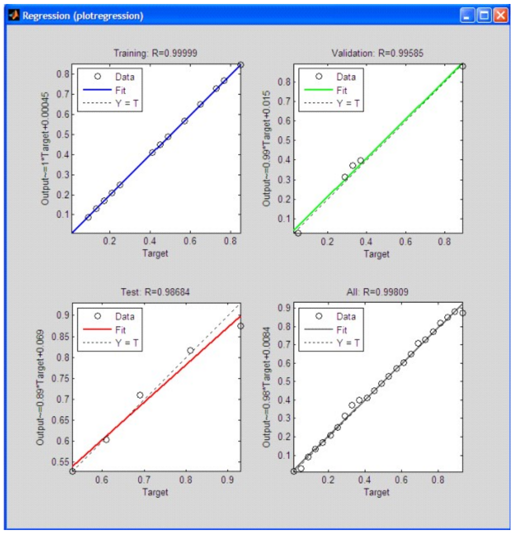

Figure 7: Regression plot for Hann window

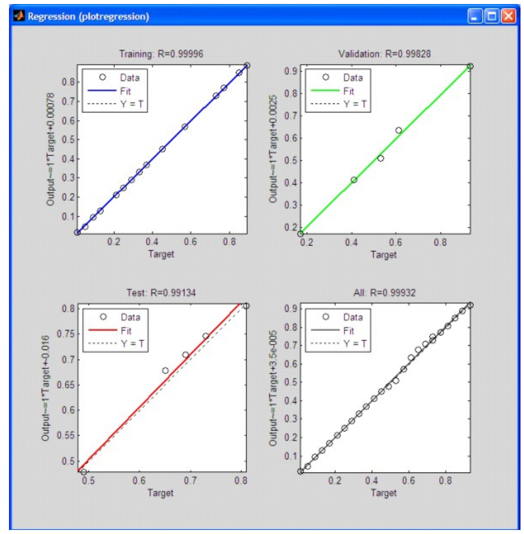

Figure 8. Regression plot for Blackman window

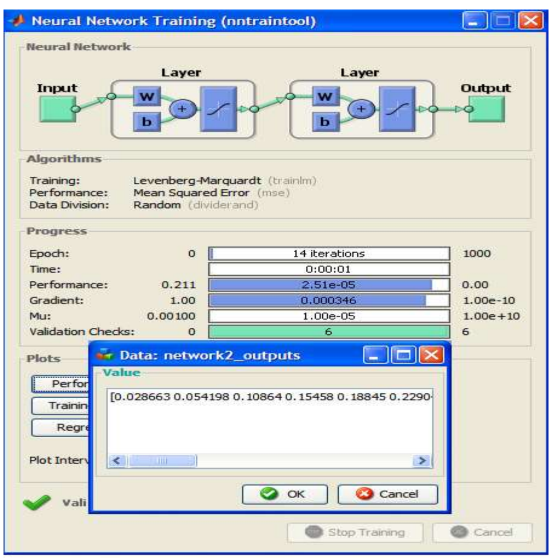

Figure 9. Results of Hann window for FFBP network

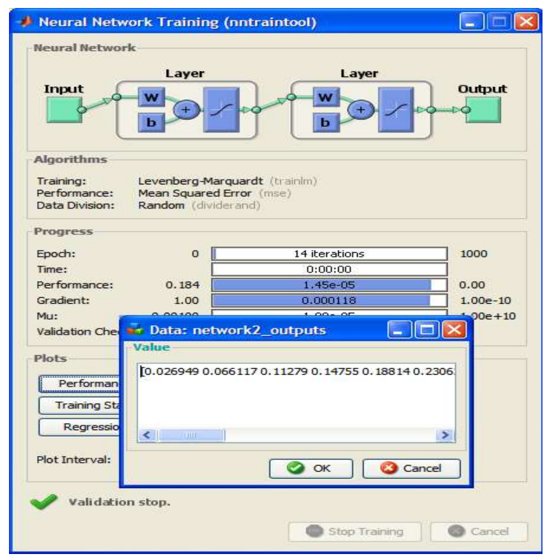

Figure 10. Results of Blackman window for FFBP Network (for 25 testing samples)

4. RESULT

Results for all cases can be shown from Table 1, 2 & 3. It is cleared from the results that we don't have to put more training samples for getting result. From this proposed work, we get the positive response in every case whether the training samples are more or less, it does not matter.

We have to train the network appropriately then only we can get the positive response at the output. Mean square error is less for Blackman window in comparison to Hann window.

Table 4: Comparison Table of MSE for Hann and Blackman window

Cases	Testing Samples	Mean Square Error	
		Hann Window	Blackman window
Case 1	13	0.001009889	0.0001454595
Case 2	20	0.0002500812	0.0002646578
Case 3	25	0.001847262	0.0004555221

5. CONCLUSION

We have designed a FIR low pass filter with Hann and Blackman window, and from the results, it is concluded that Blackman window is better than the

Hann window. Three cases had been taken in this proposed work, in first case- 37 samples are for training and 13 for testing and in second case- 30 samples are for training and 20 for testing and for the last case, there are 25 samples for training and testing, we get results in every cases but best results getting by case 1 because it contain more samples for training purpose and less for testing. And from other two cases results are found but not very accurate in comparison to case 1. So researcher can get results from every case and with any filter order but if we want appropriate result then we need to train the network with more samples.

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