Design Low Pass FIR Digital Filter for Cut off Frequency Calculation Using Artificial Neural Network

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Abstract - This paper presents a design approach of low pass FIR digital filter for cut- off frequency calculation using artificial neural network (ANN).In this work FDA Tool has been used for design of FIR low pass digital filter with Bartlett–hanning and Blackman-Harris window because high stop band attenuation has been achieved by these window and ANN has been used for cut off frequency calculation with three algorithms namely feed forward back propogation,feed forward distributed time delay and radial basis function. The cut off frequency has been compared by NN Tool and FDA Tool, comparison has been done also for windows and algorithms.

Key Words: **low pass FIR digital filter, NN Tool, FDATool, Bartlett-hanning, Blackman Harris window FFBP, FFDTD, RBF.**

1. INTRODUCTION

A filter is a device that discriminates of its input according to some attribute of the object. The digital filter can be implemented in both software and Hardware. Digital filter is a linear time invariant system (LTI) which does not vary with time. Digital filter have high accuracy, easy to simulate and design, flexible than analog filter [17]. Based on frequency characteristics digital filter is divided into four types-

Low pass filter (LPF)-Low pass filter only passes the low frequency components ($\le w_c$).
High pass filter (HPF)-High pass filter only passes the high frequency components ($\ge w_c$).
Band pass filter (BPF)-Band pass filter only passes the frequency components between two frequencies (w_{c1}&w_{c2}).
Stop band filter (SBF)-Stop band filter does not passes the frequency components between two frequency (w_{c1}&w_{c2}).
In this section discussion has been done for the design of low pass FIR digital filter.

There are two types of digital filter-

i. Finite impulse response filters (FIR).
ii. Infinite impulse response (IIR).

The impulse response of FIR filter is finite so this is known as FIR digital filter. They do not use and feedback because they depends on present input and past input so it is also known as non recursive filter.FIR digital filter has linear phase characteristics and they and inherently stable but IIR filter do not have linear phase characterstics.The impulse response of IIR digital filter is infinite so this is known as IIR digital filter. They requires feedback because they depends on present input, past input and past output so they are also known as recursive filter[10].
The output sequence is given as for FIR filter-

$$Y(n)=\sum_{K=0}^{N} h(k)x(n-k)$$
$$Y(n)=h(0)x(n)+h(1)x(n-1)+......+h(N)x(n-N)$$

This sequence of output is finite so this is known as finite impulse response.

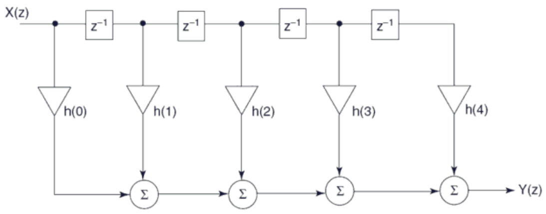

Figure 1. FIR digital filter

2. FIR DIGITAL FILTER DESIGN USING WINDOW METHOD

The window method is one of the simplest methods for design of FIR filter among the two method i.e. fourier series and frequency sampling. In the frequency sampling it only works for particular frequency components and for other it does not works. Window method is easy method and various windows can be used based on our application [5]. The desired unit sample response is given by

$$h_d(n)=\frac{1}{2\pi}\int_{-\pi}^{\pi} Hd(w)e^{iwn}\,dw$$
$$h(n)=w(n)h_d(n)$$

Where $h_d(w)$ is desired frequency response characteristics.$h_d(n)$ is of infinite duration so $h_d(n)$ is truncated by finite length of window(M-1) which is w(n).so h(n) will be of finite length duration.
In this paper two windows have been used which are-

Bartlett-hanning window-

Bartlett-hanning window is given as

$$w(n)=0.62-.48\left|\frac{n}{N-1}-0.5\right|+.38\cos\left(2\pi\left(\frac{n}{N-1}-.51\right)\right) \quad ;0\le n\ge N-1$$

Blackman Harris window-

Blackman Harris window is given as

$$w(n)=0.35875-0.4882\cos(\frac{2\pi n}{N-1})+.14128\cos(\frac{4\pi n}{N})-.01168\cos(\frac{6\pi n}{N})\quad ;0\leq n\geq N-1$$

3. ARTIFICIAL NEURAL NETWORK (ANN)

Artificial neural network is comprised of a network of artificial neurons (node) [15].neural network is an algorithm that based on the human brain works. They can build predicted model by learning the pattern of historical data.ANN made by interconnected processing element, these are known as node or neuron. Each node processes the small part of the task. The most common type of ANN is multi layer perceptron (MLP).in MLP the nodes are organized in layer. It is also known as parallel distributed processing system or connectionist system. The first layer is the input layer, the outer most layer stands for output layer. Between these two comes one or more layer known as hidden layer. The entire node is fully connected with the previous node. Input are multiplied by unique weight and added together by a small value called bias. This total is processed is by the function called the activation function.

$f(u)=w_1u_{1+}w_2u_2+w_3u_3+b$

Where w is weight is an input and b is a bias.

It leaves the node as output, this process proceeds till information reached at the output layer and leaves it as the prediction for the independent variable. The network compares predicted and actual output. If these do not match it adjust all the weight and repeat the process till the network produce an accurate prediction for most of the observation.

There is various algorithms use in ANN this are-

Feed forward back propagation- a feed forward network has feedback paths meaning they can have signals travelling using loops. This system is nonlinear dynamic system because there is a loop which changes until it reaches state of equilibrium. In this the data flows in forward direction and error flows in reverse direction.

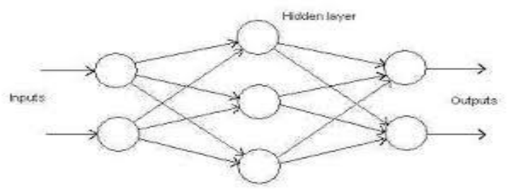

Figure 2. Feed forward network

Feed forward distributed time delay algorithm-In this algorithm whose basic function is to work on sequential data. Time delay represents the time shift usually form part of a larger pattern recognition system. It is mainly use to represent the relation between time and input.

Radial basis function- It is a real value function whose value depends only on the distance from the origin or alternatively on the distance from some other point C, called a center. The norm is usually euclidean distance although other distance function is also possible. Radial basis function has more number of neurons than other algorithm so it gives better result than another algorithm.

4. FORMULATION OF PROBLEM

The objective of this paper is to be estimated the cut off frequency of proposed filter coefficients of low pass FIR digital filter which is achieved by FDA Tool using Bartlett-hanning and Blackman Harris window. In this the input has been used as filter coefficient and target has been used as cut off frequency for which these filter coefficient have. Some filter coefficients have been chosen which works as test input and for this test input we estimate the cut off frequency using NN Tool. The comparison has been done between Bartlett-hanning and Blackman Harris window. Feed forward back propagation, feed forward distributed time delay and radial basis function algorithm of ANN also have been compared.

5. EXPERIMENTATION

Cut-off frequency of low pass FIR digital filter has been calculated with three steps-

i. **Step 1:**

Low pass FIR digital filter has been designed by FDA Tool. The order of the filter has been chosen 10.The cut off frequency has been used in the form of normalized, varied from 0 to 1.

The cut off frequency has been used say f_c.The value has been selected as fc=0.025 and designed the filter. The value of filter coefficients h(n) have been exported on workspace. The same process has been repeated for f_c from 0.025 to 0.975. Total 39 samples have been achieved. Out of these 39 samples, 30 samples have been used as training and 9 as testing.

ii. Step 2:

The MS excel file has been created for training input, target and testing input. These files have been loaded to MATLAB workspace.

iii.Step 3:

A neural network has been created by using nntool box. Training algorithms have been selected as feed forward back propagation; feed forward distributed time delay and radial basis function. After training, the network has been simulated by testing input. Then the cut off frequency has been compared by data from FDA Tool.

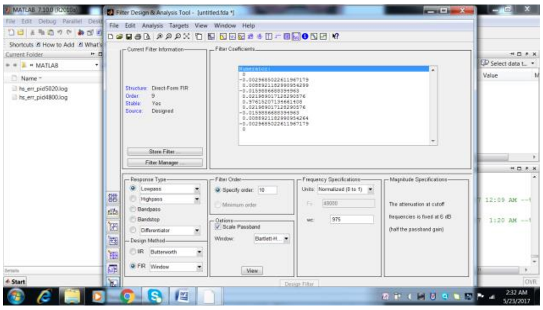

Figure 3. Filter designing by FDA Tool for Bartlett-hanning window

Cut off frequency calculation of low pass FIR digital filter using Bartlett-hanning window

a) Feed forward distributed time delay (FFDTD)

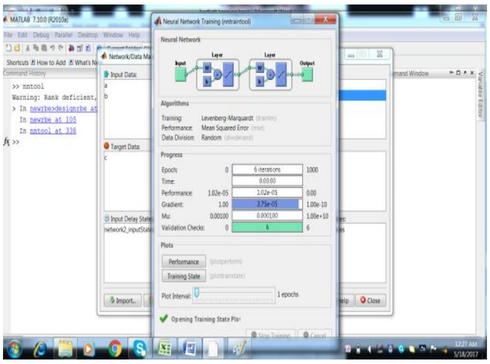

Figure 4. Trained network

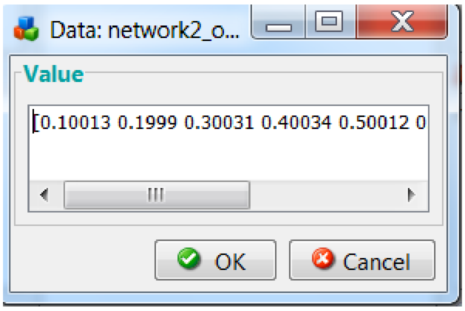

Figure 5.1 Result of FFDTD network for Bartlett-hanning window

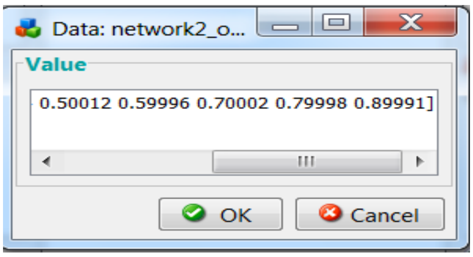

Figure 5.2 Result of FFDTD network for Bartlett-hanning window

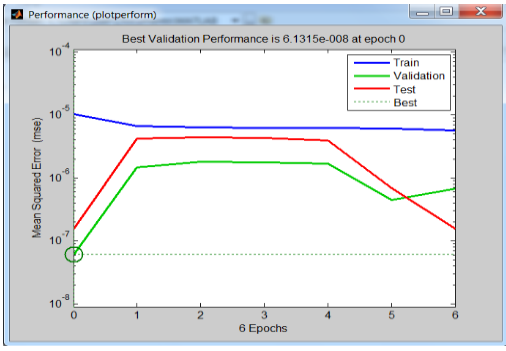

Figure 6. Performance plot for FFDTD for Bartlett-hanning window

b) Feed forward back propagation (FFBP)

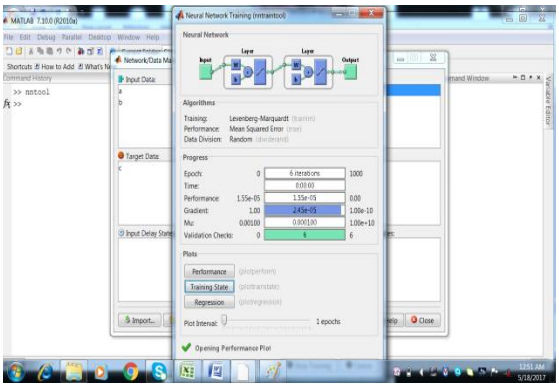

Figure 7. Trained network

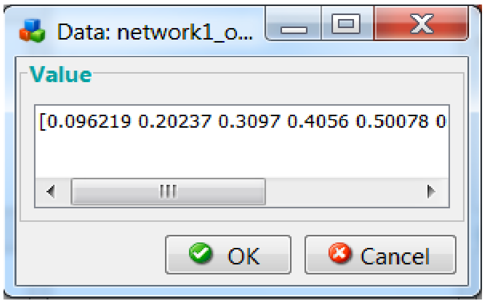

Figure 8.1 Result of FFBP network for Bartlett-hanning window

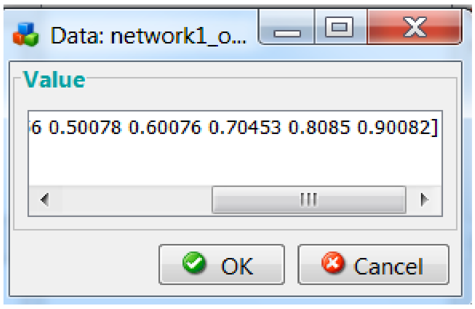

Figure 8.2 Result of FFBP network for Bartlett-hanning window

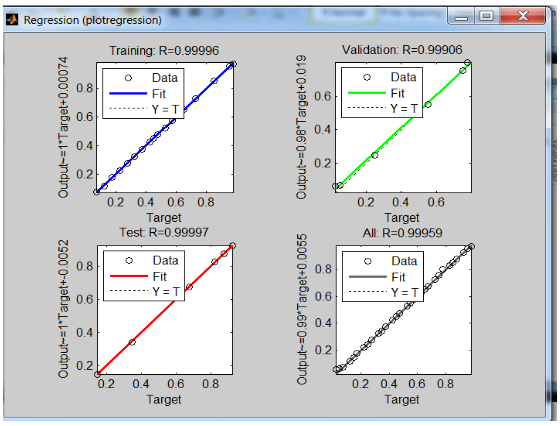

Figure 9. Regression plot of FFBP for Bartlett-handing window

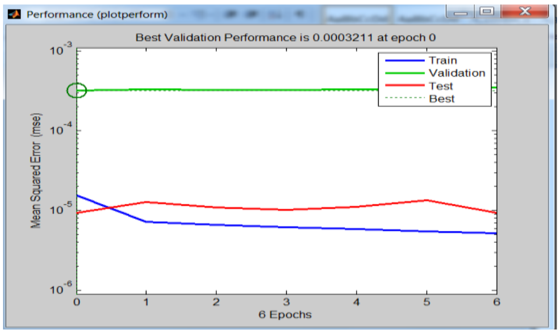

Figure 10. Performance plot for FFBP for Bartlett-hanning window

c) **Radial basis function (RBF)**

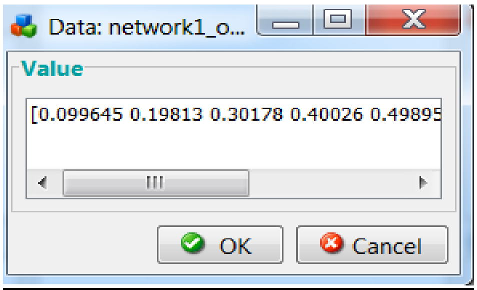

Figure 11.1 result of RBF for Bartlett-hanning window

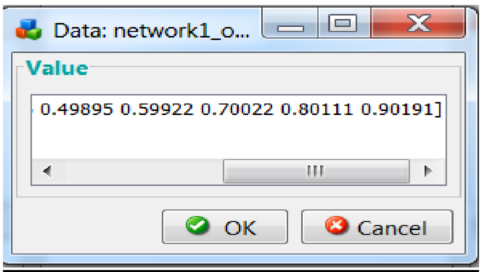

Figure 11.2 result of RBF for Bartlett-hanning window

Cut off frequency calculation of low pass FIR digital filter using Blackman Harris window

a) **Feed forward distributed time delay (FFDTD)**

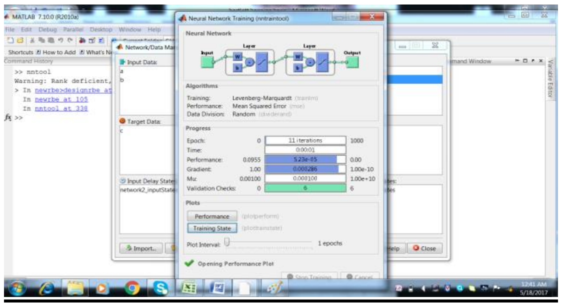

Figure 12. Trained network

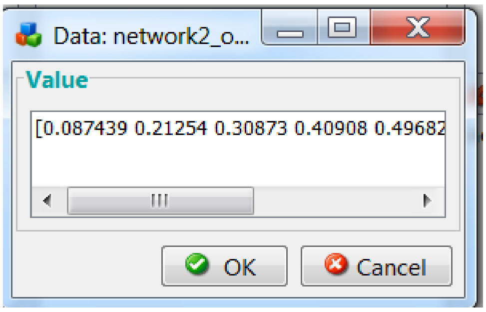

Figure 13.1 Result of FFDTD network for Blackman Harris window

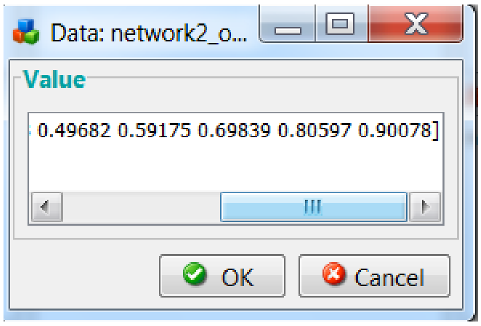

Figure 13.2 Result of FFDTD network for Blackman Harris window

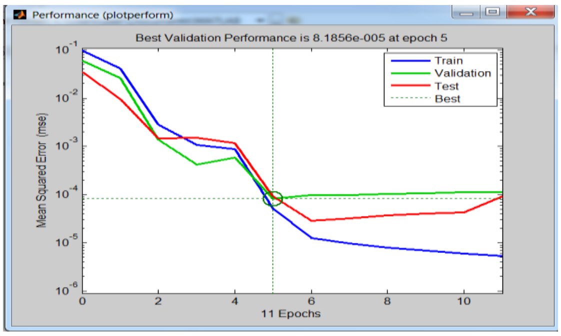

Figure 14. Performance plot for FFDTD for Blackman Harris window

b) Feed forward back propagation (FFBP)

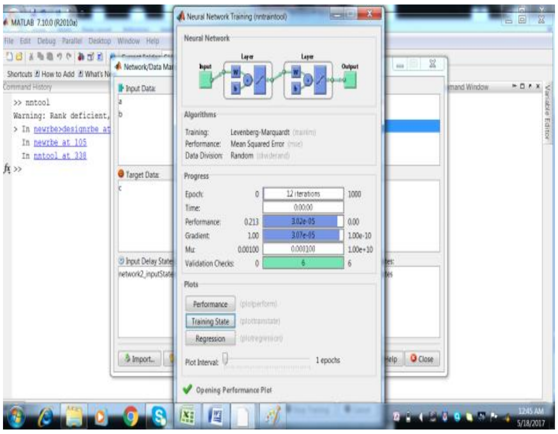

Figure 15. Trained network

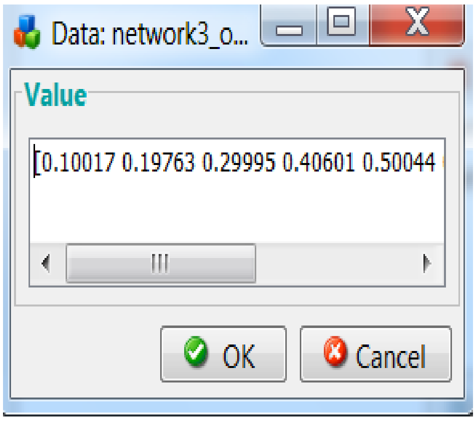

Figure 16.1 Result of FFBP network for Blackman -Harris window

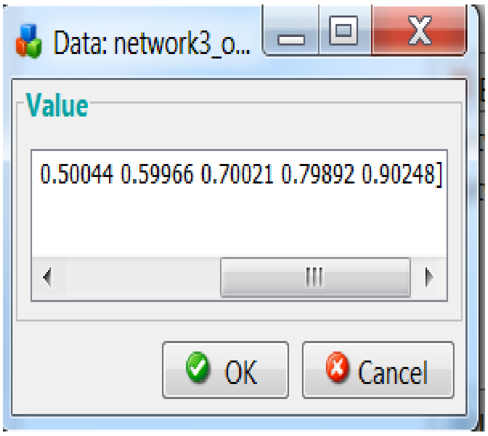

Figure 16.2 Result of FFBP network for Blackman Harris window

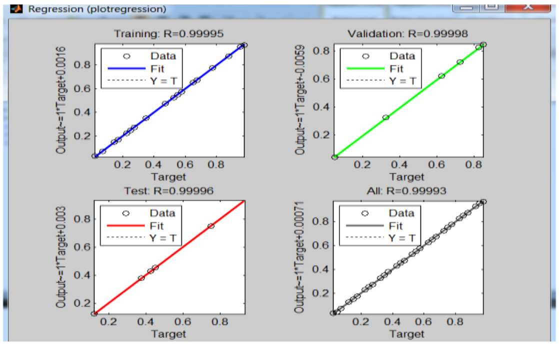

Figure 17. Regression plot of FFBP for Blackman Harris window

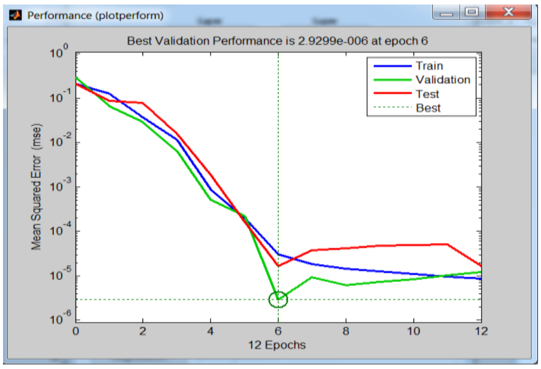

Figure 18. Performance plot for FFBP for Blackman Harris window

c) Radial basis function (RBF)

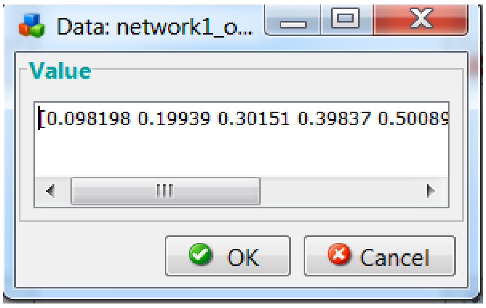

Figure 19.1 result of RBF for Blackman Harris window

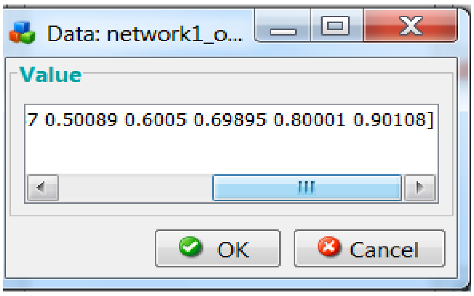

Figure 19.2 result of RBF for Blackman Harris window

Test input (Filter coefficient)	Bartlett-hanning Window (actual cut off Frequency)	Output of artificial neural network (calculated cut off frequency)			Mean square error		
		FFDTD	FFBP	RBF	FFDTD	FFBP	RBF
h(n)	f_c	f_c	f_c	f_c	f_c	f_c	f_c
$h_1(n)$	.1	.10013	.094099	.099645	.0000000169	.000034821801	.000000126
$h_2(n)$	.2	.1999	.19812	.19813	.00000001	.0000035344	.0000034969
$h_3(n)$	.3	.30031	.30522	.30178	.0000000961	.0000272484	.0000031684
$h_4(n)$	.4	.40034	.40082	.40026	.0000001156	.0000006724	.0000000676
$h_4(n)$	.5	.50012	.49661	.49895	.0000000144	.0000114921	.0000011025
$h_5(n)$	.6	.59996	.59897	.59922	.0000000016	.0000010609	.000006084
$h_6(n)$	.7	.70002	.69943	.70022	.0000000004	.0000003249	.0000000484
$h_7(n)$	.8	.79998	.80009	.80111	.0000000004	.0000000081	.0000012321
$h_8(n)$	.9	.89991	.90074	.90191	.0000000081	.0000005476	.0000036481

Table 1. Result of bartlett-hanning Window using ANN

Test input (Filter coefficient)	Blackman Harris Window (actual cut off Frequency)	Output of artificial neural network (calculated cut off frequency)			Mean square error		
		FFDTD	FFBP	RBF	FFDTD	FFBP	RBF
h(n)	f_c	f_c	f_c	f_c	f_c	f_c	f_c
$h_1(n)$	.1	.087439	.10017	.098198	.0001577778721	.0000000289	.0000032472
$h_2(n)$	.2	.21254	.19763	.19939	.0001572516	.0000056169	.0000003721
$h_3(n)$	.3	.30873	.29995	.30151	.0000762129	.0000000025	.0000022801
$h_4(n)$	.4	.40908	.40601	.39837	.0000824464	.0000361201	.0000026569
$h_4(n)$	.5	.49682	.50044	.50089	.0000101124	.0000001936	.0000007921
$h_5(n)$	.6	.59175	.59966	.6005	.0000680625	.0000001156	.00000025
$h_6(n)$	.7	.69839	.70021	.69895	.0000025921	.0000000441	.0000011025
$h_7(n)$	.8	.80597	.79892	.80001	.0000356409	.0000011664	.0000000001
$h_8(n)$	.9	.90078	.90248	.90108	.0000006084	.0000061504	.00000011664

Table 2. Result of blackman-harris Window using ANN

6. RESULT

In this experiment two tables have been acheived.first is for Bartlett-hanning window, second is for blackman-harris window. By help of the table 1 and 2. Various error graphs between desired and obtained frequency are drawn for various windows.

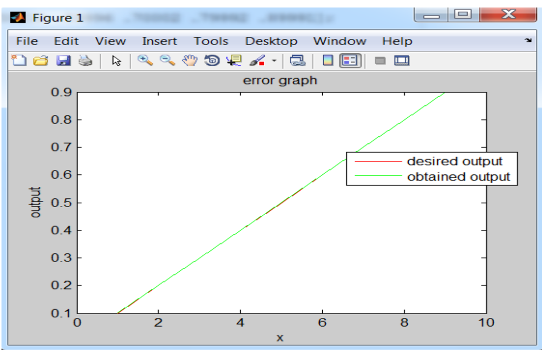

Figure 20. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Bartlett-hanning window with FFDTD

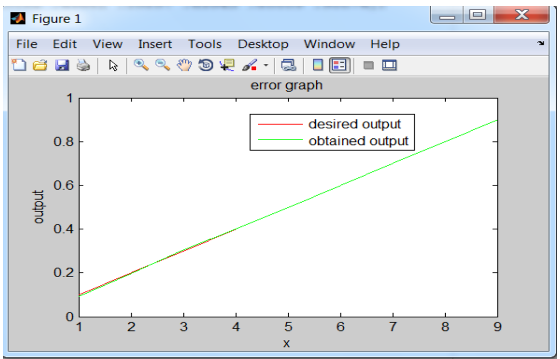

Figure 21. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Bartlett-hanning window with FFBP

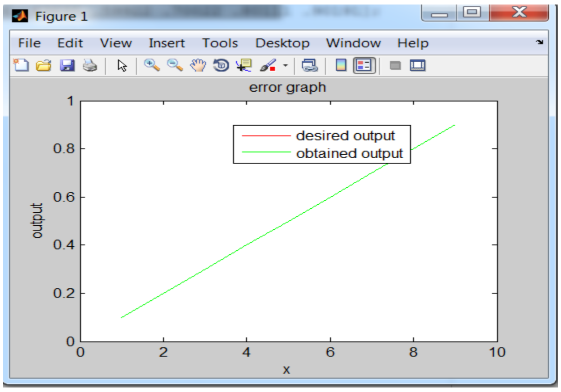

Figure 22. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Bartlett-hanning window with RBF

Figure 20, 21 and 22 shows error graph between desired cut-off frequency and obtained cut-off frequency for Bartlett-hanning window with FFDTD, FFBP and RBF.

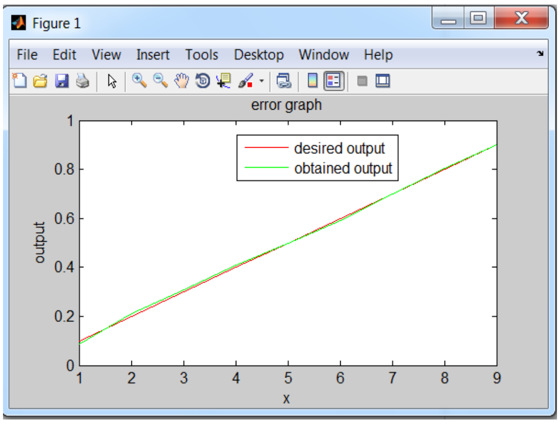

Figure 23. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Blackman-harris window with FFDTD

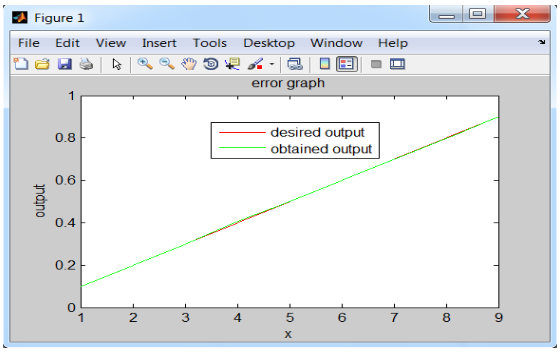

Figure 24. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Blackman-harris window with FFBP

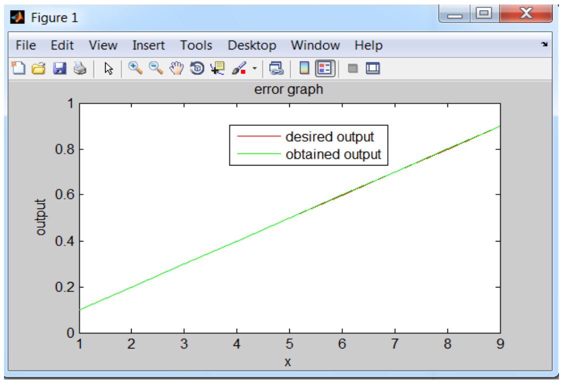

Figure 25. Error graph between desired cut-off frequencies and obtained cut-off frequencies for Blackman-harris window with RBF

Figure 23, 24 and 25 shows error graph between desired cut-off frequency and obtained cut-off frequency for Blackman-Harris window with FFDTD, FFBP and RBF.
The cut off frequency have been calculated from ANN using NN Tool and it can be easily seen that there is very less difference between actual and calculated cut off frequency. In this 39 samples have been used for training and 9 for testing. So we have seen ANN gives efficient result in less time and it has been given result nearer to the actual one.

7. CONCLUSION

For finding that which window gives better result the mean square error (MSE) has been achieved for each window and for each algorithm. After this it has been found that both windows are given almost same result but Blackman -Harris window is given the more efficient result than Bartlett-hanning window. Out of three algorithms i.e. FFDTD, FFBP and RBF, it has been found from various error graphs that RBF is best and better result is achieved by this almost same as actual one.RBF has highly accurate algorithm than other.

8. REFERANCE

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