Adaptive Noise Cancellation using NLMS Algorithm in GNU Radio

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***Abstract*— In this paper, an adaptive noise cancellation technique using NLMS algorithm in GNU radio is proposed. In adaptive noise cancellation, the noise free signal is obtained by estimating the noise and interference and then adaptively filtering them out from the received signal. In this method, an adaptive noise canceller recovers the desired signal corrupted by noise using NLMS (Normalised Least Mean Square) algorithm. The experiments are carried out with a normal cosine signal source and an audio signal in GNU Radio. The results obtained show the effective operation of NLMS algorithm in adaptive noise cancellation.**

Keywords—Adaptive filter; Normalised Least Mean Square (NLMS); GNU Radio; Noise Cancellation.

I. INTRODUCTION

The process of recovering a signal distorted by additive noise involves passing this distorted signal through a filter which adaptively removes the noise component, the original signal will be retained and the pure signal can be recovered back. This approach is called the direct filtering. Direct filtering are of two types Fixed or Adaptive.

- Fixed filters - This type of filters are designed for in a specific frequency band. The filter passes only the bands of the required signal and rejects the band of noise frequencies. The design of this filter requires prior knowledge of both signal and noise [1].

- Adaptive filters - Adaptive filters are designed such that they adapt their impulse response in a manner so as the correlated signal in the input is filtered out. Prior information or knowledge of the noise and the signal characteristics is not required or required in least amount. The adaptive filter utilises a desired signal and this desired signal will be having a correlation to the signal which is to be estimated. Moreover adaptive tracking of the signal under non-stationary conditions can be done using adaptive filters.

Noise Cancellation is another version of optimal filtering where the noise estimate is made by doing some filtering operation on the reference signal input. The estimated noise is then subtracted from the input which is a mixture of signal and noise which is also referred as primary input [2]. The subtraction of noise signal may lead to distortion of the actual signal, thereby amounting to more noise. This can be overcome by making the noise estimate exact replica of the noise. Producing such an estimate effectively is difficult as the transmission path is unknown and unpredictable. Hence an adaptive process is used for the purpose of filtering and subtraction. An adaptive filter which has the capability of adjusting its impulse response is employed for minimizing the error signal, which is dependent on the filter output. An adaptive algorithm performs the tap weight adjustment which in turn adjusts the impulse response of the filter. The adaptive control facilitates noise reduction without the risk of signal distortion in any manner. The noise removal efficiency of adaptive filter is better that is a higher noise rejection level can be obtained which is not possible by the direct filtering process. Minimization of the mean square error, the temporal average of the least squares error etc. are the criterion used. Least Mean Squares (LMS), Normalised Least Mean Squares (NLMS) algorithms etc. are the different algorithms used for the minimization criteria. LMS is the basic algorithm others are the higher versions of the LMS algorithm which are more efficient. Here, the noise cancellation is carried out using the Normalised Least Mean Square algorithm (NLMS) [3]. The experiments are done separately in GNU Radio Companion for a normal signal source and an audio signal.

This paper begins with Section II, in which Normalised Mean Square Algorithm (NLMS) is discussed. In Section III a brief description about the GNU Radio software is given. Section IV gives an outline about the creation of NLMS block in GRC. Section V gives the details regarding the experiments conducted.

II. NORMALISED MEAN SQUARE ALGORITHM

NLMS filter belongs to the LMS filter family. The sensitivity to the scaling of the filter input is a major drawback of LMS algorithm. NLMS is an advanced form of the LMS algorithm.

Input power normalization is done in NLMS algorithm. The NLMS adaptive filter principle is same as

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that of LMS filtering terms of structure as shown in Fig 1. But the weight control mechanism is different from LMS in case of NLMS algorithm [4]. The error estimation is done by subtracting the output of M-by-I tap-input vector from the desired response [5]. Until a steady state is obtained by the filter, the sequence of the above events will be repeated. Here in Fig.1, the filter output is represented by *y(n)*.

$$y(n) = w^H(n).u(n) \quad (1)$$

where *w(n),* is the current tap-weight vector estimate and *u(n)* is the input to the filter. Hermitian is represented by superscript *H*. Estimation error is represented by *e(n)*.

$$e(n) = d(n) - y(n) \quad (2)$$

Desired response of the filter is represented by *d(n)* .

$$w(n+1) = w(n) + (\mu / ||u(n)||^2)\, e(n)u(n) \quad (3)$$

Above shown is the NLMS algorithm in which *w(n+1)* represents the tap weight vector estimate at the time *(n+1)* and μ is a constant.

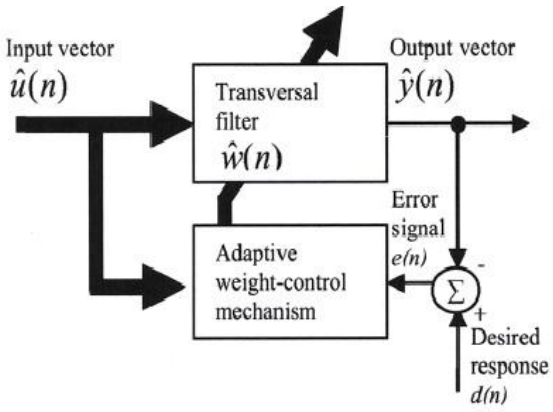

Fig. 1. Block Diagram of Adaptive Transversal Filter

III.GNU RADIO

GNU Radio is a free and open software radio ecosystem that provides framework to implement software defined radios and signal processing system. It is a highly modular, ”flow graph”-oriented framework that comes with a comprehensive library of processing blocks that can be readily combined to make complex signal processing applications [6]. GNU Radio has been used for a huge array of real-world radio applications, including audio processing, mobile communications, tracking satellites, radar systems, GSM networks etc. Analog and digital communication systems can be developed using GNU Radio with USRP [7]. It is used to develop and implement any band-limited communication standard. GNU Radio can be used for simulation purposes or interfacing external communication hardware. GNU Radio has provisions for FFT displays, symbol constellation diagrams and scope.

GNU Radio Companion

The GNU Radio Companion is a Graphical User Interface which consists of mainly signal processing blocks which are written in python codes [8]. On clicking the search option in GNU radio companion we will get the list of inbuilt blocks on the right side of the window. Our own blocks according to the application can be made by writing the python or c codes [9], machine learning block creation in GNU radio companion is discussed in [10]. Many communication and signal processing simulations can be done GNU radio companion.

IV.CREATION OF NLMS BLOCK IN GNU RADIO

In GRC, a new block called Adaptive noise canceller nlms is created to perform the function of adaptive noise cancellation. This nlms block is created in the ADAF module. Out of tree module is used to create the module gr adaf. gr modtool script is used create files automatically. Empty files for the block nlms is created. Then a .cc file is created where the code for performing nlms algorithm is written. After the coding part is done, build and compile operations are performed to successfully create the block.

V.EXPERIMENTS

Experiments using a normal cosine signal source

In this experiment, adaptive noise cancellation for a normal

Cosine signal is carried out. The signal is corrupted by noise. In GRC, newly created nlms block performs the adaptive filtering. The corrupted signal is given as one of the inputs to this block and the desired signal, i.e. the cosine signal is given as another input. The flow graph for the experiment is shown in Fig.2.

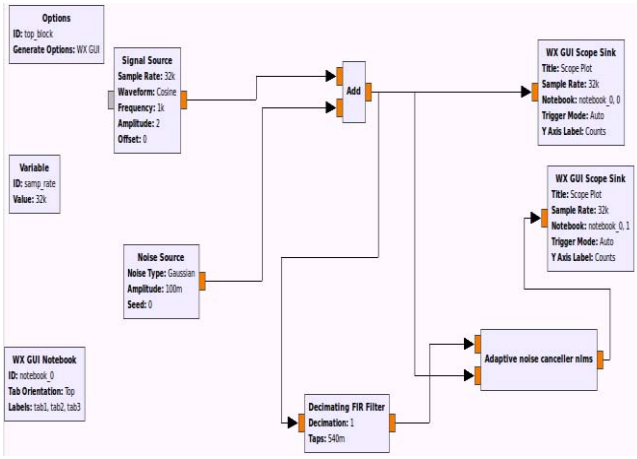

Fig. 2. Flow graph for Experiment using Cosine signal source

The signal corrupted by noise is shown in Fig.3. The output filtered waveform is shown in Fig.4. It can be seen from the output filtered waveform that the noise has been adaptively removed to a greater extent.

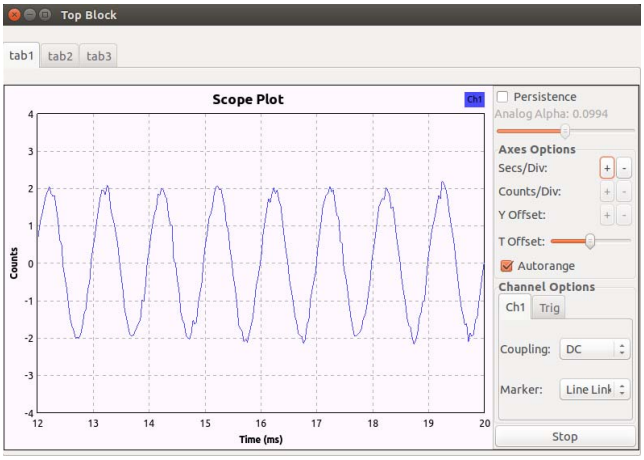

Fig. 3. Corrupted Signal

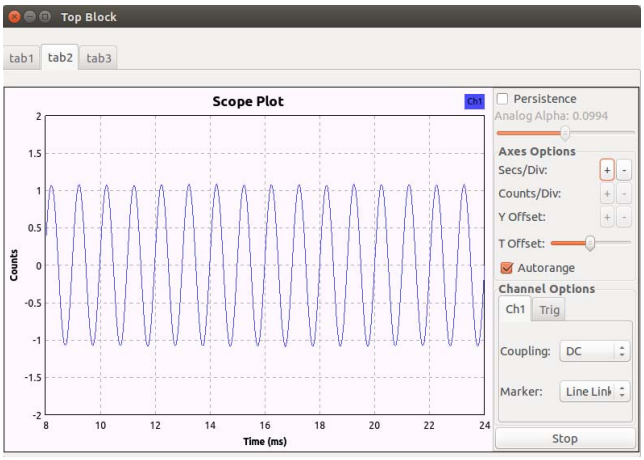

Fig. 4. Filtered Output

A. Experiment using an audio signal

This experiment uses an audio signal instead of a normal cosine waveform. The audio signal used here is a .wav file which is supported by wav file source block in the GRC. Then the procedure is carried out in the same manner as that of the first experiment using the nlms block. The flow graph for the experiment, corrupted signal and filtered output are shown in Fig. 5, Fig. 6 and Fig. 7 respectively.

The audio signal corrupted by noise is shown in Fig. 6. The adaptively filtered audio signal is shown in Fig. 7. It is seen that noise in the audio signal has been adaptively filtered out to obtain a signal free of noise.

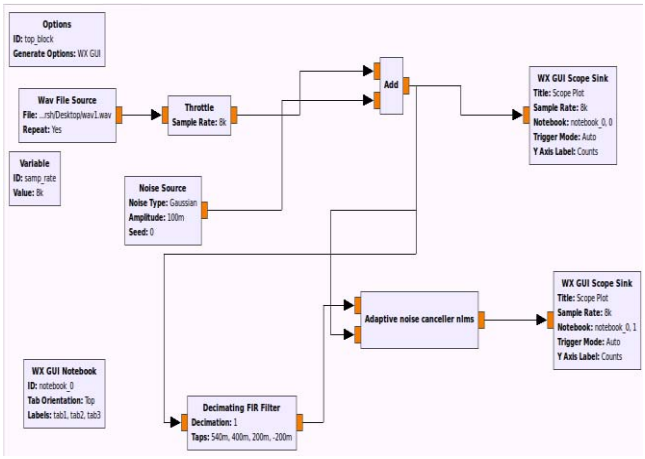

Fig. 5. Flow graph for Experiment using audio signal

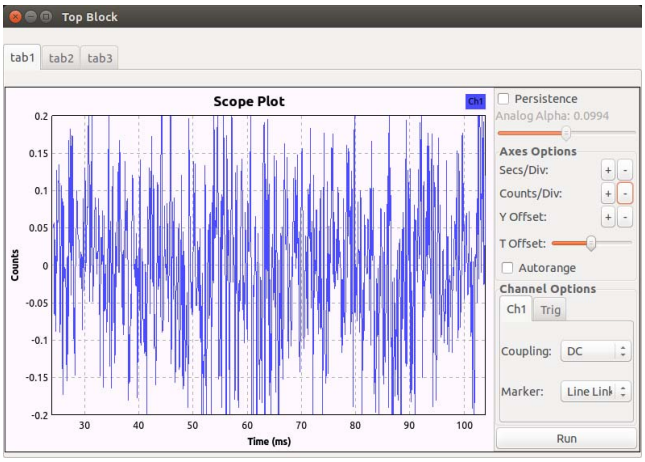

Fig. 6. Corrupted Audio

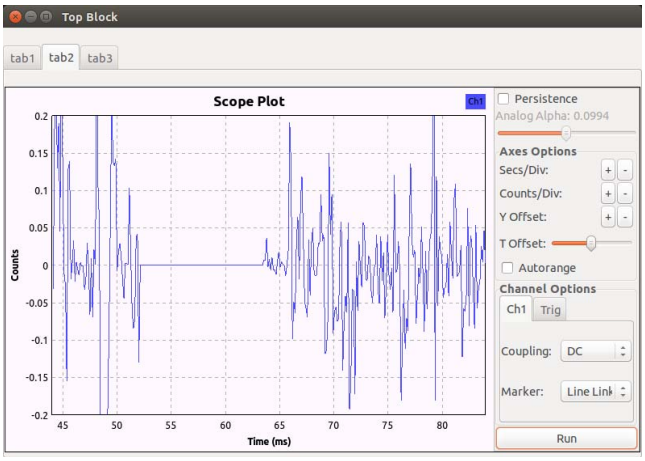

Fig. 7. Filtered Output

VI.CONCLUSION AND FUTURE WORKS

This paper proposed an adaptive noise cancellation technique using NLMS in GNU Radio. From the results of both the experiments, it is seen that the noise has been adaptively removed to obtain the desired signal. This technique can be used in various applications to make the acoustic signal free of noise for easy processing in the further stages of operation. A robust speaker verification system can be developed by combining this proposed system with an HMM model.

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