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MITIGATION OF GPS MULTIPATH EFFECTS USING ADAPTIVE NORMALIZED LMS ALGORITHM

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ABSTRACT

The objects surrounding the GPS receiver easily distorts the satellite signal. With the increasing Global Navigation Satellite System (GNSS) based applications, they require reliable and accurate navigation solutions in challenging environments such as urban communities. In such situations, receiver accuracy and reliability are restricted due to multipath signals. Multipath is the phenomenon of propagation in which the signals travelling through two or more paths are received by the receiver. Multipath signals are those received signals other than LOS signal by antenna. Multipath signal is the combination of the direct as well as indirect signal. Finally, multipath leads to poor measurement accuracy and fading. In this paper Normalized LMS adaptive filter algorithm is mainly used to mitigate multipath signals. Other adaptive filters are also have been implemented to compare the results.

Keywords: multipath, NLMS, LMS, GNSS.

1. INTRODUCTION

The GPS signal [1] when travelling through the space it undergoes many distortions. At higher latitudes it is distorted by ionospheric scintillations, whereas at lower latitudes multipath effect comes into play. Due to multipath the accuracy of positioning varies as well as the precision is also effected [1]. The multipath is mainly caused by the reflections from surfaces and shadowing effects caused by obstruction of buildings which is shown in Figure-1. The multipath effect varies based up on the weather and the surroundings. Multipath signals consist of time delayed signals [2].

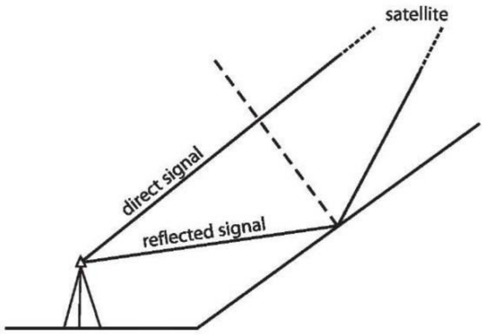

Figure-1. Multipath propagation.

In order to reduce the multipath effect we are using adaptive filters. In adaptive filtering the weight coefficients of the filter are adjusted by feedback loop. The parameters of the filters are modified with respect to time. Adaptive filters have wide applications in such as noise cancellation, signal prediction, echo cancellation and channel equalization [2].

The steps involved in adaptive filtering process are:

a) The input GPS signal is given to the filter as well as the adaptive weight control mechanism.
b) The output of the filter is calculated with reference to the input signal.
c) The error is obtained by taking difference between desired signal and output of filter.
d) Based upon the input signal, error and past weights the present weights are updated.

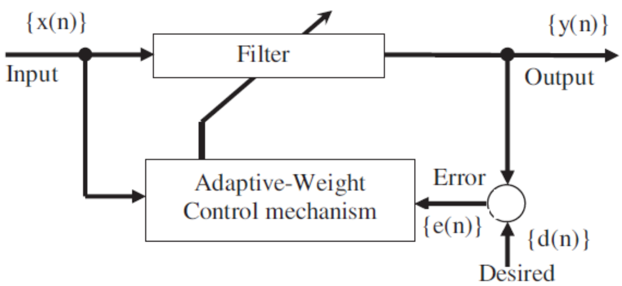

Figure-2. Adaptive filter block diagram.

A FIR digital filter is used in this adaptive filtering process. The weights are adjusted by help of the algorithm. The output is obtained by multiplying the input signal and the weight coefficients. The error is calculated based on steepest descent algorithm [3]. This algorithm depends upon the selecting the step size (μ). Based on the updated weight coefficients and the desired signal, the output change. A FIR low pass filter with a cut-off frequency of 0.25 Hz is designed to mitigate the multipath.

The input signal x_i(n) is the multipath signal which is given to the adaptive filter [1]. The desired signal $d(n)$ is taken by adding the multipath series signal with the response of filter. The input signal does not correlate with the desired signal. The output of the adaptive filter is denoted by $y(n)$ and the error is given by $e(n)$.

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2. LEAST MEAN SQUARE (LMS) ALGORITHM

The Least Mean Square (LMS) algorithm is an adaptive filter algorithm which is normally known as stochastic gradient-based adaptive algorithm [4]. The weights converge on optimal weiner solution by using modified filter weights. It will be broadly utilized due to its less computational complexity. With each iteration of Least Mean Square algorithm the filter coefficients are updated. The updated filter weight coefficients are calculated according to the following formula [2]:

$$h(n+1) = h(n) + 2 * \mu * x_i(n) * e(n) \tag{1}$$

whereμ is the convergence or step size parameter,
x_i(n) represents the input signal,
h(n) represents the filter coefficients, given by

$$x_i(n) = [x_i(n)x_i(n-1)x_i(n-2) \ldots x_i(n-N+1)]^T \tag{2}$$

$$\mathrm{h(n)} = [\mathrm{h_0(n)h_1(n)h_2(n)} \ldots \mathrm{h_{N-1}(n)}]^{\mathrm{T}} \tag{3}$$

The convergence step size is chosen for vital of the performance of LMS algorithm. The output diverges and the stability of system decreases by considering large μ value. If the value of μ is very small, the filter takes long time to converge [5], [6].

3. NORMALIZED LEAST MEAN SQUARE (NLMS) ALGORITHM

When the step size or convergence parameterμ is large, there will be amplification of noise in Least Mean Square algorithm. NLMS algorithm can be used for solving this problem. The convergence parameter is adjusted with reference to the input signal. Thus the convergence factor orstep-size parameter is said to be normalized [8].

The weight coefficients h(n) at $n+1^{th}$iteration becomes normalized by using squared Euclidian norm of the input signalx_i(n). NLMS algorithm can be termed as time-varying step-size algorithm. The step factor μ in NLMS algorithm is calculated by [2].

$$\mu(n) = \frac{\alpha}{c+|x(n)|^2} \tag{4}$$

whereα denotes the Normalized LMS adaption constant. It should satisfy the condition 0<α<2. The constant term is always less than 1, which is denoted by c [9] [10].

The filter coefficients are updated by the following equation [2]

$$h(n+1) = h(n) + \frac{\alpha}{c+|x(n)|^2} e(n) x_i(n) \tag{5}$$

The Normalized LMS adaptive algorithm updates the filter weight coefficients so that the value H (n+1) shows a small change with the known value of H(n).
Steps involved in NLMS Algorithm:

1. The filter output is given by[2]

$$y(n) = \sum_{i=0}^{N-1} h(n)x_i(n-i) = h^T(n)x_i(n) \tag{6}$$

2. The difference between desired signal and filter signal gives error signal [2]

$$e(n) = d(n) - y(n) \tag{7}$$

3. The convergence step size (μ) is calculated as [2]

$$\mu(n) = \frac{\alpha}{c+|x(n)|^2} \tag{8}$$

4. The filter coefficients are updated by the following equation[2]

$$\mathrm{h(n+1)} = \mathrm{h(n)} + \frac{\alpha}{\mathrm{c}+|\mathrm{x(n)}|^2} \mathrm{e(n)x_i(n)} \tag{9}$$

4. RESULTS AND DISCUSSIONS

The satellite data is recorded at KL University from the satellite G03 on 29 June 2013 as shown in the Figure-3(a), for conducting the experiment. It is observed that SNR values are varied up to plus or minus 3m indicated severe multipath. The multipath GPS signal is considered as input to NLMS algorithm for mitigating multipath effects.

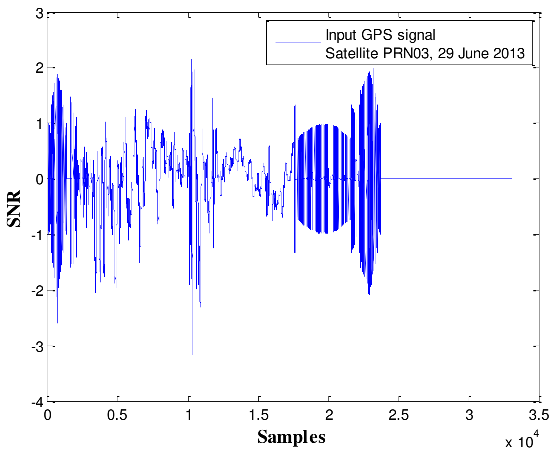

Figure-3. Input GPS signal observed at KL University by GNSS Receiver.

The amount of error can be found out using $[\frac{(Y)}{X}] * 100$ in percentage. The X and Y denote mean multipath errors before after the filtering. The value of X for the taken input signal from Figure-4 is 79cm. The values of Y are 10.89 cm and 4.59 cm for LMS and NLMS output filtered signals respectively. By using LMS filter the error is reduced by 78.6% as shown in Figure-5 and by using the NLMS filter it is reduced by 91.42% as shown in Figure-6.

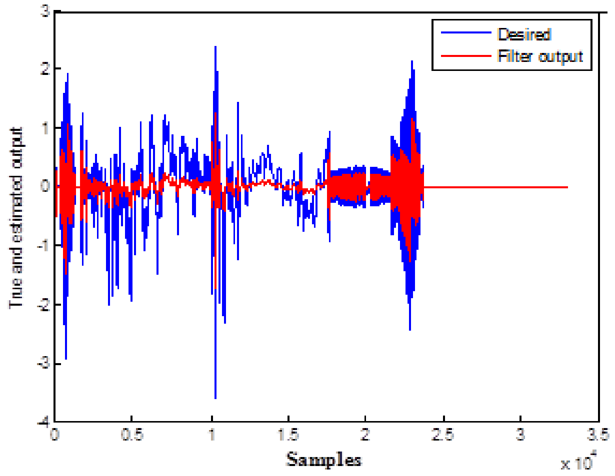

Figure-4. True and estimated output of LMS filter.

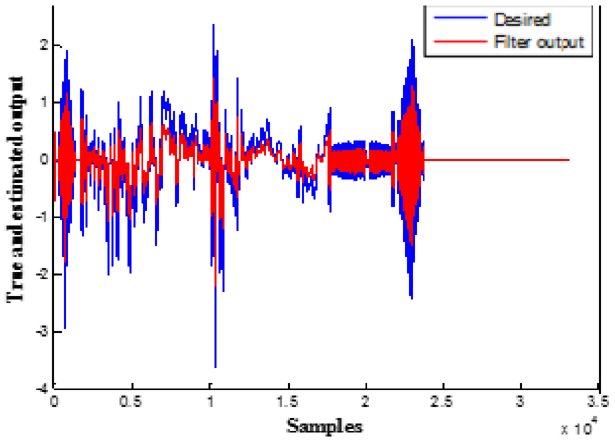

Figure-5. True and estimated output of NLMS filter.

The performance criterion of adaptive filters is measured based up on reduction in error signal as shown in Figures 7 and 8.

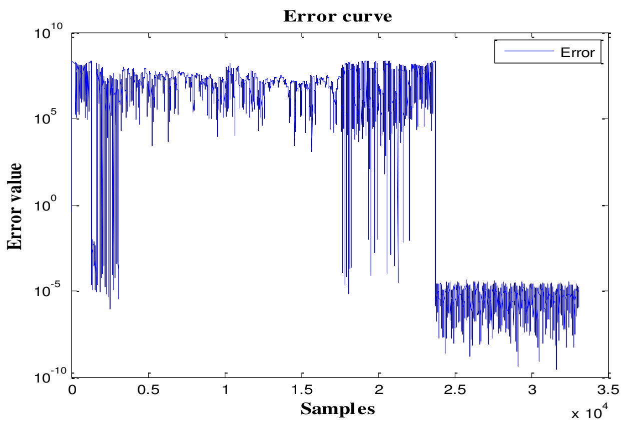

Figure-6. Error curve of LMS filter.

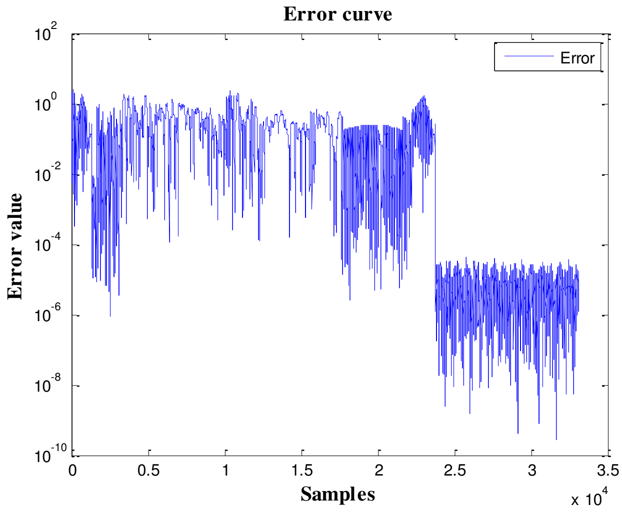

Figure-7. Error curve of NLMS filter.

The NLMS filter has better efficiency than the LMS filter. For higher convergence speeds, data with high sampling and in large amount are to be taken.

5. CONCLUSIONS

In this paper NLMS algorithm has been used as a prime algorithm. The results obtained from LMS and NLMS are compared based on their performance. These are implemented using MATLAB. The convergence in LMS algorithm is slow when compared to the NLMS algorithm. Step size has to be chosen correctly in order to obtain good results. The LMS algorithm is the simplest when compared to the NLMS. Due to normalized step parameter the convergence speed is high in NLMS. The GPS data is taken from K L University at 29 June 2013 from satellite G03. The future work will be carried out by developing robust adaptive filters for multipath effects on GNSS signals.

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