AN RLS BASED ADAPTIVE TRANSVERSAL FILTER FOR GPS NARROWBAND INTERFERENCE CANCELLATION

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ABSTRACT:

GPS signals are susceptible to interference levels above the inherent processing gain of the receiver. In this paper an innovative approach to cancel narrowband interference is presented. An Adaptive Temporal Filter (ATF) based on a Transversal form that pre-filters the interference before correlation is studied. The adaptive algorithm used to adjust the filter coefficients is the RLS algorithm. The RLS algorithm has faster convergence and is independent of the gradient step size when compared to LMS or NLMS algorithms. Simulation studies showed that the RLS based algorithm outperforms both LMS and NLMS in terms of convergence, RMS error and acquisition performance.
Key words: GPS, narrowband interference, RLS, Adaptive Transversal Filter, RMS error, Acquisition, ISLR

1.INTRODUCTION

Global Positioning System (GPS) is finding its place in large number of applications. It is well known that like any other radio signal, GPS is most easily disrupted at the receiver RF front-end whereas the signal modulation itself may be resistant to any impact. It is required to provide robust performance under jamming scenarios. The common jammers are of narrowband type, which are either CW or pulsed. Narrowband interference can substantially degrade the performance of the global positioning system (GPS). While the GPS signal has inherent resistance to such interference through its processing gain, in certain scenarios the gain is inadequate and additional remedies must be sought against this problem. A class of well-known techniques uses pre-filtering before correlation to sharply reduce the interference power out of the filter while having little effect on the desired GPS signal, as in [1]. Adaptive filters are used for non-stationary signals and environments, or in applications where a sample-by-sample adaptation of a process or a low processing delay is required. The filter can be formed in the time domain using an adaptive transversal filter (ATF), as in [2].

The organization of the paper is as follows: In Section 2, the Adaptive Transversal Filter structure which is used for interference cancellation is presented and we also summarize the adaptive algorithm that is used to control the weights of the transversal filter. In Section 3, we present the simulation, results and observations. Section 4 concludes the interference cancellation technique.

2. TRANSVERSAL FILTER STRUCTURE

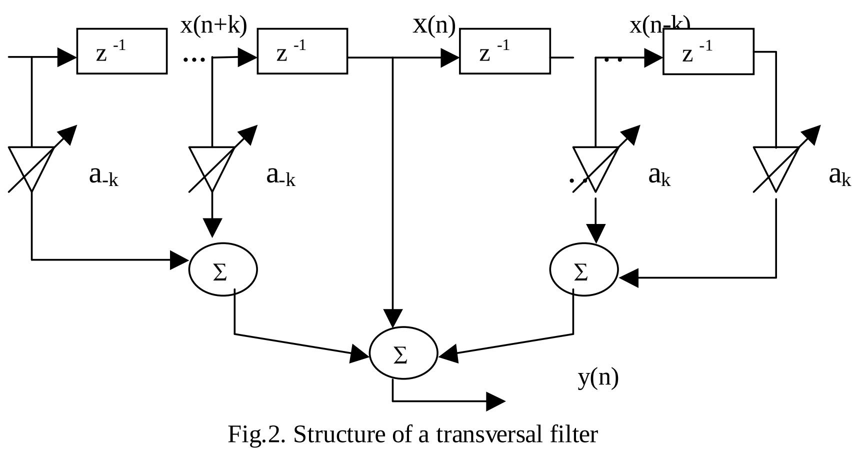


Fig.2. Structure of a transversal filter

The GPS signal of the form $X(n)=[x(n+k)_{.......}x(n)_{.......}x(n-k)]^T$ is fed into transversal filter, that computes a corresponding output signal sample y(n) at time n,as in [3]. Each tap's weight is updated after every sampling clock so that for an N-tap filter there are N updates as the signal moves down the delay line. The output signal y(n) is given by (1)

$$y(n)= x(n) + \sum_{k=1}^{N} a_{-k}\, x(n+k)+ \sum_{k=1}^{N} a_k\, x(n-k) \tag{1}$$

where a_k's are the tap weights that are adaptively changed and n is the time index.
The output signal is compared to a second signal d(n), called the desired response signal which is taken from the centre tap by subtracting the two samples at time n. This difference signal is given by (2)

$$e(n) = d(n)–y(n) \tag{2}$$

is known as the error signal. This error signal is used to control the weights at each update thereby making it adaptive.

2.1 Recursive Least Squares Algorithm

An adaptive filter starts at some initial state, and then the filter coefficients are periodically updated, usually on a sample-by-sample basis, to minimize the difference between the filter output and a desired or target signal. The adaptation formula has the general recursive form:
Next parameter estimate = Previous parameter estimate + Update (error)
where the update term is a function of the error signal.

The adaptation process is based on the minimization of the mean square error criterion defined as

$$E[e^2(m)] \;=\; E\,\{[\;x(n) – a_k\, y(n)]^{\,2}\} \tag{3}$$

The Wiener filter is obtained by minimizing this mean square error with respect to the filter coefficients. The RLS filter has a relatively fast rate of convergence to the optimal filter coefficients.

In the recursive least square algorithm, the adaptation starts with some initial filter state, and successive samples of the input signals are used to adapt the filter coefficients. The Recursive Least squares (RLS) algorithm provides a recursive procedure that computes present weights from its past values, as in [4]. The RLS algorithm has faster convergence and it is independent of the gradient step size, as in [5]

The weight update equation is given by (4)

$$w(n) = w(n\text{-}1) + g(n)\, e^*(n) \tag{4}$$

Where * denotes complex conjugate
w(n) is an Nx1 column vector of tap weights, g(n) is the adaptation gain and e(n) is the error signal

Adaptation gain g(n) is given by (5)

$$g\,(n) \;=\; \frac{P\,x(n)}{P\,x\,(n)\,x\,(n)^{H}} \tag{5}$$

$P=R^{-1}(n)$ =Inverse covariance matrix of x(n)

The error signal e (n) is given by (6)

$$e(n) = y(n)\text{-}w^{H}\,(n\text{-}1)x(n) \tag{6}$$

The RLS algorithm updates the required $R^{-1}(n)$ using the previous inverse and present sample by (7)

$$P = \frac{P\,(I - g\,(n)\,x\,(n)^{H})}{\lambda} \tag{7}$$

Where λ is a real small scalar close to unity, used for exponential weighting of past data and hence called as forgetting factor, as in [6] and $()^{H}$ denotes Hermetian.

3.RESULTS AND OBSERVATIONS

The simulations were carried out using the GPS signal, as in [7] corrupted with two narrowband discrete tone interferences. No. of Taps used N=2M+1=33. The signal is sampled at 5MHz after down conversion and the desired signal is obtained from the main channel by means of delay.

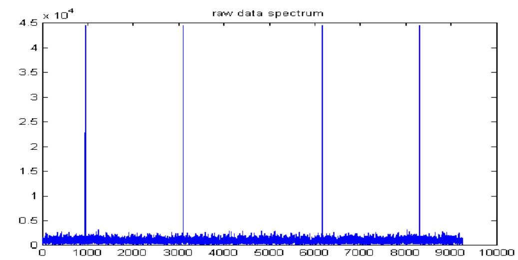
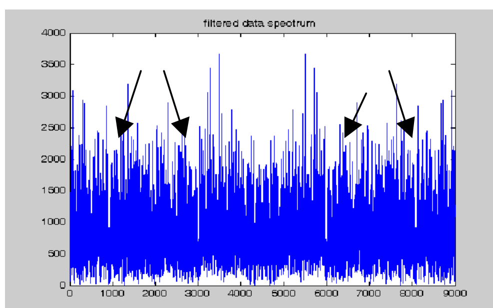


Fig.2. Data spectrum of the GPS signal along with the generated interference signals with SNR=-15dB,JNR=20dB,No.of samples=9000



amplitude

No. of samples

Fig.3. Filtered Data spectrum, which shows that the high interfering peaks are cancelled

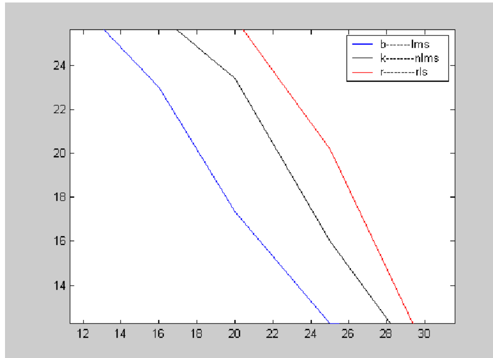
Integrated Side Lobe Ratio is defined as the ratio of peak power to the average energy.

$$ISLR = \frac{x_{max}^{2}}{1/N \sum |x^{2}|} \tag{8}$$

Where xmax is the highest energy peak in the plot and N is the total number of samples =9000

The performance of the filter was studied after post correlation to check the Integrated Side Lobe Ratio (ISLR). The ISLR measure gives the energy spill over to the side lobes and gives a quantitative measure for the algorithm performance in terms of acquisition. The ISLR performance was checked for different jammer powers and are as given below.

ISLR



Jammer to Noise Ratio (JNR)

Fig.4. Plot of ISLR Vs JNR for various Adaptive algorithms

4. CONCLUSIONS

In this paper a technique to prefilter narrowband interference using adaptive structures is presented. GPS interferences sources are likely to be narrowband and low power. Such sources can cause outages to GPS receivers due to poor filtering. Adaptive Transversal filters, when compared against the other available techniques offer a great deal of promise in mitigating these sources effects on GPS reception. The performance measure adopted to check the algorithm is the acquisition performance. It is found from simulation that RLS outperforms both LMS and NLMS in terms of Integrated Side Lobe Ratio (ISLR).

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