



AN AUTOREGRESSIVE BASED LFM REVERBERATION SUPPRESSION FOR RADAR AND SONAR APPLICATIONS

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ABSTRACT

In a real time noisy environment scenario, improving the target detection performance is one of the most important issues when active sonar and radar systems are used for target detection. In this paper, we are aiming to suppress reverberation that is present while transmitting a Linear Frequency Modulated (LFM) signal. The motivation behind this paper is to convert the LFM reverberation to whiten using parameter based Autoregressive (AR) model. As LFM reverberation is a frequency dependent which is severely colour noise, so we are focused to attain stationary frequency and the adjacent signal block is used as a reference signal of proposed technique. The study of performance comparison of parametric based AR prewhitening using Levinson-Durbin and Burg methods were studied with respect to LFM reverberation suppression and results are presented using MATLAB tool

Keywords: *Linear Frequency Modulated Signal, Reverberation and Autoregressive.*

I. INTRODUCTION

Noise is an uncontrollable component as it is frequency independent. Reverberation is a self generated controllable noise which is frequency dependent. While detecting a low speed targets, Reverberation and Cluttering deeply affects the target detection performance of active sonar and radar systems respectively. If Reverberation exists, it is difficult to distinguish the actual and fault targets. As Reverberation is severely colored, correlated strongly with the emitted signal and non stationary in both frequency and time domain, matched filter fails to give the optimized output. Reverberation or cluttering cannot be eliminated completely but can be suppressed using different signal processing techniques. Prewhitening technique is mainly used to whiten the reverberation before applying to matched filter. In active sonar and radar systems, the term like autoregressive (AR) have been used for modeling processes like reverberation suppression similar to all-pole filtering mode

1.2 LFM SIGNAL

In the radar literature, LFM is known to be easily generated by a variety of technology and has a superior performance in pulse compression. Pulse compression is used to increase range resolution and signal to noise ratio. To transmit a long pulse that has a bandwidth corresponding to a short pulse, pulse compression technique is required. Linear frequency modulation (LFM or chirp) signals are widely used in

information systems. Linear frequency modulation is a technique used to increase the waveform bandwidth while maintaining pulse durations such that $\tau \gg 1/\beta \Rightarrow$ Time-bandwidth product $\beta\tau \gg 1$.

A linear frequency modulated signal is defined as

$$l_{fm}(t) = e^{j2\pi(f_0 t + \frac{mt^2}{2})} ; \quad \text{for } 0 \leq t \leq T$$

$$= 0 ; \quad \text{otherwise}$$

The instantaneous frequency of the LFM signals is given by

$$f_i(t) = d(f_0 t + (BW / 2T)t^2) / dt$$

$$= f_0 + (BW / T)$$

II. ADVANTAGES OF LFM SIGNAL

Increasing the duration of transmitted pulse increases its energy and improves target detection capability; conversely, reducing the duration of a pulse improves the range resolution of the radar. Pulse compression techniques enable to decouple the duration of the pulse from its energy by effectively creating different durations for the transmitted pulse and processed echo.

III. AR MODEL

In AR model the future values are estimated based on the weight sum of past values. A time-varying autoregressive (TVAR) approach is used for modelling non-stationary signals, and frequency information is then extracted from the TVAR parameters. An auto regressive model is also known in the filter as an infinite impulse response filter or an all pole filter

$$X_t = \sum_{i=1}^N a_i x_{t-i} + e_t$$

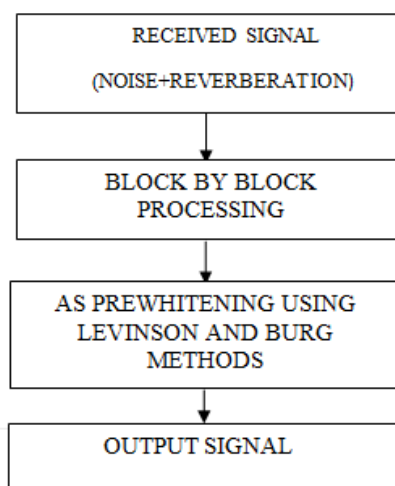
where a_i -autoregressive coefficients

X_t -series under investigation

N -order of the filter

All zero model (in statistics, moving average (MA) model). Mixed pole-zero model is called auto regressive moving average (ARMA) model)

3.1 Prewhitening Processing



Step 1. To generate transmitted signal using linear frequency modulated signal with low and high speed conditions

Step 2. Divide the received signal into blocks using a sliding window.

Step 3. Whiten the current signal block with AR prewhitening in time domain.

Step 4. Compare Levinson and burg method results

3.2 Yule-Walker Equations

The linear relationship between $\gamma_{xx}(m)$ and the $\{a_k\}$ parameters. these equations called the yule- walker equations can be expressed in the matrix form

$$\begin{bmatrix} \gamma_{xx}(0) & \gamma_{xx}(-1) & \gamma_{xx}(-2) & \dots & \gamma_{xx}(-p) \\ \gamma_{xx}(1) & \gamma_{xx}(0) & \gamma_{xx}(-1) & \dots & \gamma_{xx}(-p+1) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \gamma_{xx}(p) & \gamma_{xx}(p-1) & \gamma_{xx}(p-2) & \dots & \gamma_{xx}(0) \end{bmatrix} \begin{bmatrix} 1 \\ a_1 \\ \vdots \\ a_p \end{bmatrix} = \begin{bmatrix} \sigma_u^2 \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

This matrix is symmetric, but is also toeplitz matrix, which means the inverse can be performed efficiently, using an iterative algorithm.

3.3 Levinson_Durbin Algorithm

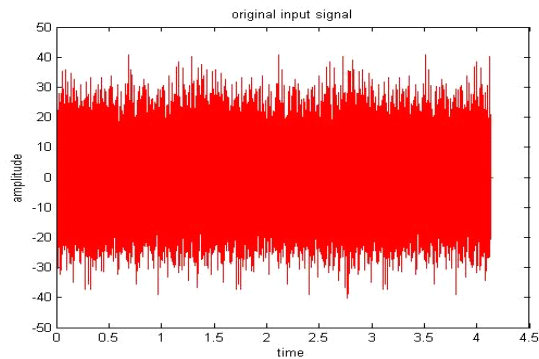
In p^{th} order forward linear predictor, the current sample of speech is predicted from a linear combination of p -past samples. Levinson algorithm is achieved by the minimizing the MSE of the forward prediction error and then applying the toeplitz feature of the auto correlation matrix, a fast algorithm based on order recursion is derived by levinson. Source code can be found in the software packet, because of this algorithm is based on the solution of toeplitz autocorrelation matrix it is also called autocorrelation method. the levinson durbin algorithm is computationally efficient algorithm for solving the normal equations for prediction coefficients

3.4 Burg Algorithm

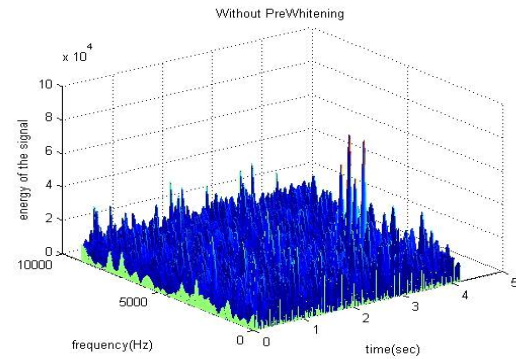
Autoregressive (AR) modelling is used for analyzing stationary stochastic processes for many different applications, e.g., radar geophysics, and economics. A comparison of various estimators of AR-parameters showed that the Burg algorithm is the preferred estimator for AR-parameters. The Yule-Walker algorithm can be severely biased. After a large true reflection coefficient, estimates for higher order reflection coefficients suffer from a bias of order 1 instead of the smaller bias of order $1/N$ that is present in other estimation methods. The least squares estimator and the forward-backward least squares estimator have a greater variance than Burg. In addition, they may yield unstable models. In many applications, the duration of one uninterrupted measurement is submitted to practical limitations. However, it is often possible to obtain several separate segments of data. The Burg algorithm

IV. RESULTS AND TABLES

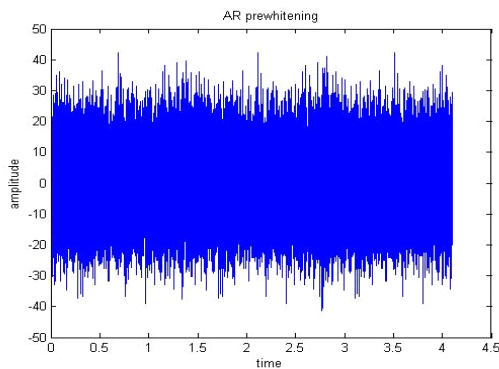
Levinson_Durbin results



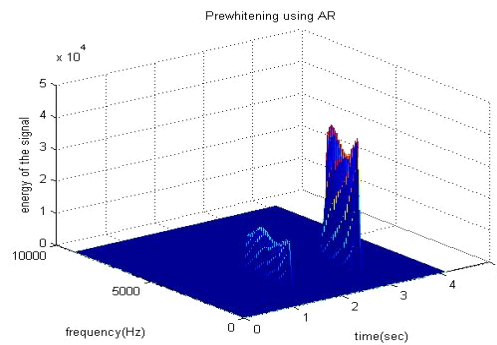
1 (a)



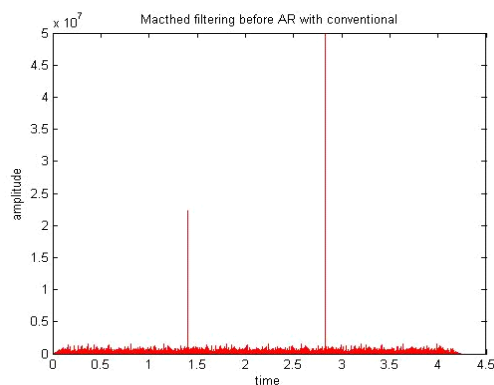
1(b)



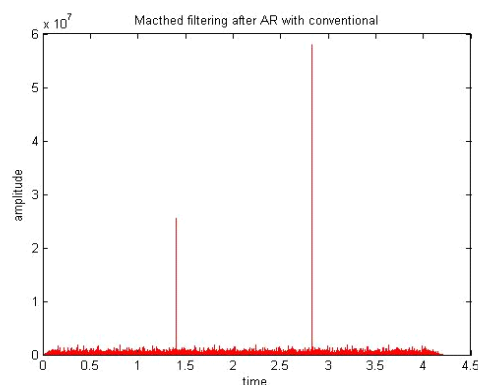
1 (c)



1 (d)



1(e)



1 (f)

Fig.1: Target detection results at $p=10$ & $SNR=20db$ at Levinson_Durbin

1 (a) before prewhitening in time domain

1 (b) before prewhitening in mesh plot

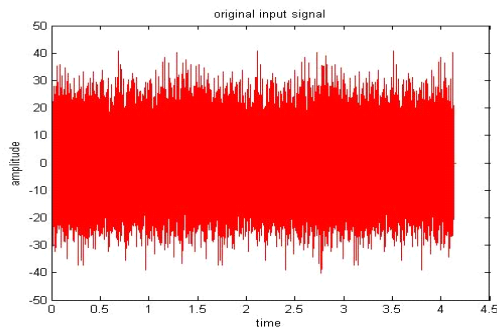
1 (c) after prewhitening in time domain

1(d) after prewhitening in mesh plot

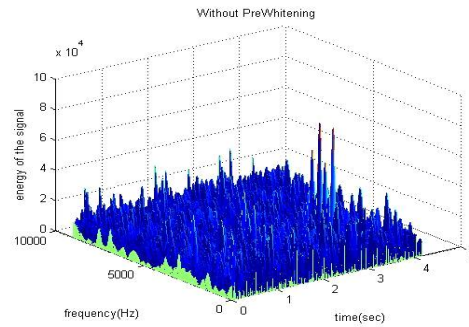
1 (e) matched filter output before prewhitening

1 (f) matched filter output after prewhitening

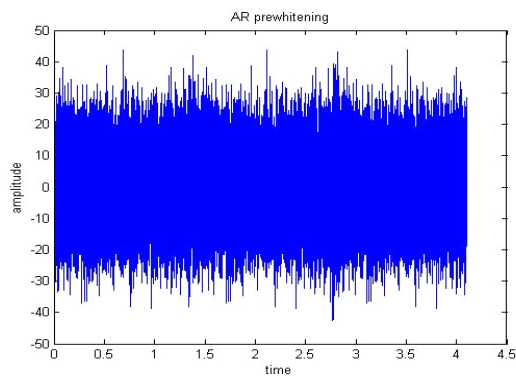
BURG RESULTS



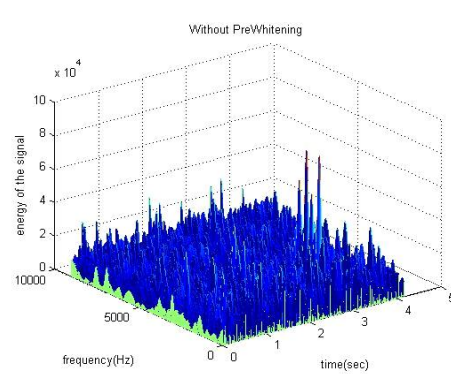
2 (a)



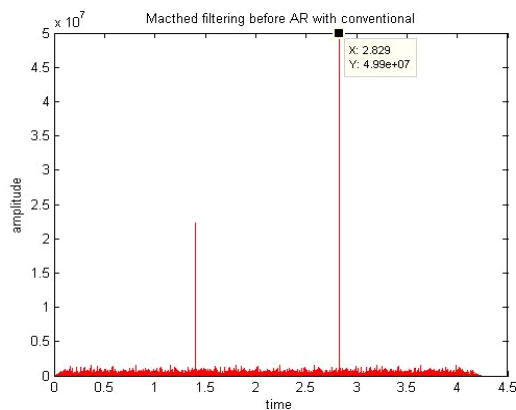
2(b)



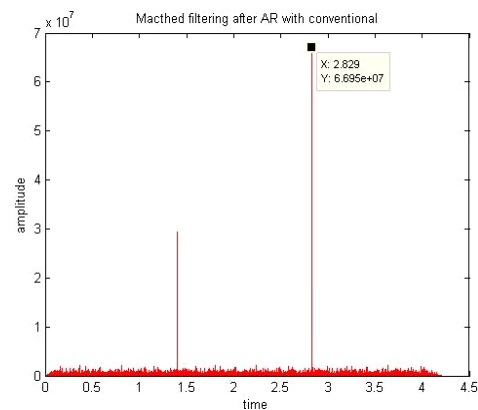
2(c)



2(d)



2 (e)



2 (f)

Fig.2: Target detection results at $p=10$ & $SNR=20db$ at burg

2 (a) before prewhitening in time domain

2 (b) before prewhitening in mesh plot

2(c) after prewhitening in time domain

2 (d) after prewhitening in mesh plots

2 (e) matched filter output before prewhitening

2 (f) matched filter output after prewhitening

Figure(1) shows the target detection results using levinson_durbin methods at filter order(p) =10 and $SNR =20$ db.fig.1(a)&1(b) shows target detection results before prewhitening at low speed targets at $t =1.4$ and amplitude is 1.932×10^7 .at high speed target s $t =2.892$ and amplitude is 4.338×10^7 .figure 1(c)&(d) shows target detection results after prewhitening at low speed targets at $t = 1.4$ and amplitude is 1.928×10^7 ,. at high speed targets at $t = 2.892$ and amplitude is 1.928×10^7 .fig 1(e)&1(f) are matched filter outputs before and after prewhitening.

Figure((2) shows the target detection results using burg methods at filter order(p) =10 and SNR =20 db fig.2(a)&2(b) shows target detection results before prewhitening at low speed targets at $t = 1.4$ and amplitude is 2.225×10^7 at high speed target $s t = 2.892$ and amplitude is 4.99×10^7 figure 2(c)&(d) shows target detection results after prewhitening at low speed targets at $t = 1.4$ and amplitude is 2.93×10^7 , at high speed targets at $t = 2.892$ and amplitude is 6.645×10^7 .fig 2(e)&1(f) are matched filter outputs before and after prewhitening.

1. COMPARING THE RESULTS BEFORE & AFTER PREWHITENING BY USING LEVINSON_DURBIN AT DIFFERENT SNR LEVELS

SNR	AMPLITUDE			
	LEVINSON-DURBIN METHOD			
	BEFORE PREWHITENING		AFTER PREWHITENING	
	Low speed target at $t=1.4$	High speed target at $t=2.892$	Low speed target at $t=1.4$	High speed target at $t=2.892$
20 db	1.932×10^7	4.338×10^7	1.928×10^7	4.358×10^7
15 db	2.189×10^7	4.812×10^7	2.301×10^7	5.043×10^7
10 db	1.988×10^7	4.72×10^7	1.983×10^7	4.615×10^7
5 db	2.007×10^7	4.782×10^7	2.042×10^7	5.282×10^7
0 db	1.925×10^7	4.91×10^7	1.975×10^7	5.632×10^7
-5 db	2.022×10^7	4.924×10^7	2.014×10^7	4.915×10^7
-10 db	2.038×10^7	4.931×10^7	2.032×10^7	4.906×10^7
-15 db	2.007×10^7	4.919×10^7	2.123×10^7	5.21×10^7
-20 db	2.016×10^7	4.917×10^7	2.043×10^7	4.968×10^7

2. COMPARING THE RESULTS OF BEFORE & AFTER PREWHITENING BY USING BURG AT DIFFERENT SNR LEVELS

SNR	AMPLITUDE			
	BURG METHOD			
	BEFORE PREWHITENING		AFTER PREWHITENING	
	Low speed target at $t = 1.4$	High speed target at $t = 2.892$	Low speed target at $t = 1.4$	High speed target at $t = 2.892$
20 db	2.225×10^7	4.99×10^7	2.93×10^7	6.645×10^7
15 db	2.189×10^7	4.812×10^7	2.422×10^7	5.291×10^7
10 db	2.074×10^7	4.94×10^7	2.669×10^7	6.575×10^7
5 db	2.069×10^7	4.883×10^7	2.278×10^7	4.364×10^7
0 db	2.006×10^7	4.85×10^7	2.003×10^7	4.827×10^7
-5 db	2.013×10^7	4.87×10^7	1.84×10^7	4.445×10^7
-10 db	1.996×10^7	4.919×10^7	2.273×10^7	5.623×10^7
-15 db	2.013×10^7	4.915×10^7	1.813×10^7	4.422×10^7
-20 db	2.016×10^7	4.918×10^7	1.982×10^7	4.902×10^7



IV. CONCLUSION

In this paper the study of performance of the AR prewhitening method for LFM reverberation suppression has been explored. The simulation results are analyzed by performing AR prewhitening on the received signal data. Simulation result analysis with received signal data proves that the proposed method is levinson-durbin method provide an improved whitening performance .In future, moving average (MA) and autoregressive moving average (ARMA) methods would be used to suppress reverberation.

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