

An Efficient Parametric Model-based Framework for Recursive Frequency/Spectrum Estimation of Nonstationary Signal

¹Kantipudi MVV Prasad, ²Dr. H.N. Suresh, ³Rajanikanth Aluvalu

¹Research Scholar, Visvesvaraya Technological University, Belgaum, India

²Department of Instrumentation Bangalore Institute Technology, Bangalore, India

Department of CSE, Vardhaman College of Engineering, Hyderabad, India

*Corresponding author E-mail: ¹prasadb2016@gmail.com

Abstract

The manuscript intends to design a general form of computationally efficient parametric mechanism based model to estimate the recursive frequency/spectrum and describe the nonlinear signals which consists of diverse degrees of nonlinearity and indiscreet units. The time variant frequency estimation is defined as the as a time-varying model recognizable proof issue in which faulty/failure data are evaluated by model coefficients. In this, an estimation approach of QR-disintegration based recursive slightest M-gauge (QRRLM) is utilized for estimation of recursive time-vareint model coefficients in non-linear environment condition by utilizing M-estimation. Here, a Variable Forgetting Factor Control (VFFC) are designed to enhance the execution of QRRLM mechanism in nonlinear condition. In this, a hypothetical deduction and re-enactments approaches were used which helps to perform VFFC determination. The resultant VFFC-QRRLM estimation can confine and limit the faulty units while dealing with different degrees of nonlinear variations. Recreation comes about demonstrate that the proposed VFF-QRRLM calculation is more vigorous and exact than traditional recursive minimum squares-based techniques in evaluating both time-shifting narrowband recurrence segments and broadband otherworldly segments with incautious parts. Potential uses of the proposed technique can be found in quality force checking, online deficiency location, and discourse examination.

Keyword: Spectral Estimation, M-Estimation, Recursive Frequency Estimation, Time-Varying Linear Model, Variable Forgetting Factor.

1. Introduction

The nonlinear signals frequency and spectrum estimation have the applicability in many areas like monitoring power quality [1], analysis of vibration [2], analysis of biomedical signals [3], speech processing [4] etc. The classification for the estimation of frequency and spectrum mechanisms can be considered as parametric or non-parametric mechanisms [5]. The parametric approaches includes modelling of Auto-Regressive-Moving-Averages (ARMA) or Auto-Regressive that assumes particular model to generate the spectrums as well as signals which is computed by model coefficients which are estimated by integrating data with the model. While in case of non-parametric mechanisms, the signals are consists of special functions like sinusoides in discrete Fourier transform or in wavelet transform (DFT or WT) and magnitude and input signal phase at certain degree of input signals at various frequency ranges which can be estimated by fitting or filtering.

In case the considered model is proper and its corresponding signal to noise ratio (SNR) is quite high, then parametric approach will have significant role yielding better frequency resolution than the analysis of broadband signals performed with nonparametric mechanism. The estimation of frequency and spectrum with the help of parametric approaches are commonly used in the linear design model which have the output dependency over the input. For the estimation of the AR spectrum, the combination of outputs will have both the previous outputs and excitation noise.

The mechanism least square (LS) estimates the linear model coefficients that performs the minimization of the mean square error (MSE) of sequence noise. For the estimation of frequency, the linear prediction mechanism is mainly uses the set of sinusoids which are obtained from the roots of polynomials generated by Linear prediction (LP) coefficients.

This paper implements a general form of parametric mechanism which perform the estimation of recursive spectrums and frequency of random signals which may offers various extents of spectral variations and the impulsive factors/components. The proposed model in this paper is developed on the basis of Recursive Least-M (RLM) estimation approach to identify the TVLM by utilizing the 1) M-function estimation function for coefficients safeguard from adverse impact of impulsive components and 2) adaptive and variable exponential windows to deal with various kind of spectral variations. The work of RLM [3] and [4] is implemented by utilizing the structure of QR decomposition (QRD) which helps to minimize the round off error and enhance the efficiency in hardware realization. In order to address the performance of limited tracking of traditional QRD based RLM i.e., QRDLM under nonlinear conditions, a Variable Forgetting Factor Control (VFFC) scheme is designed. The exponential window size is much related to the forgetting factor (FF) and is selected from a desired candidate set to lower the M-estimate errors (MEEs). From, theoretical analysis prospective, the MEE_VFFC scheme performance is almost near to the optimal parameter. Due to the existence of high computational complexity in MEE_VFFC, a low complex VFFC

scheme based on approximated derivative VFFC (ADVFFC) scheme coefficients are introduced to perform real time processing than MEEVFF scheme, the ADVFFC scheme which exhibit least computation with slight performance degradation.

The simulation outcomes suggests that the VFFC-QRRLM mechanism can help to achieve the significant improvement in the performance tracking over the conventional RLS/RLM mechanisms in the estimation of recursive frequency and spectrum. The other filtering techniques like state regulation and local polynomial regression (LPR) which can be integrated with VFFC-QRRLM for performance enhancement.

In order to analyze the performance of the proposed VFFC-QRRLM mechanism, the problems of a) robust estimation of frequency for real value sinusoidal signals and b) estimation of ARMA spectral signals with impulsive components. Here the first problem is involved with the LP based models which are best choice for signals having multiple sinusoids which takes place in power system that ensures power stability. The second problem is associated with the general form of narrowband and broadband spectra.

The proposed system utilization provides that that the proposed VFFC-QRRLM algorithm can significantly ensure the estimation of time variant frequency and spectrum and is best suited for practical applications. The performance analysis of this algorithm is performed by comparing the outputs of proposed algorithm with traditional RLS or RLM with fixed forgetting factors. The VFFC significance is that it offers faster response with less lag. In comparison with the traditional non-parametric spectral mechanisms which exhibit higher time lag in the estimation of online spectral because of two sided time window utilized. The VFFC-QRRLM mechanism only uses the previous data and hence it is capable for extraction of time varying spectral factors with least lags.

This paper is composed of the basis of different recursive frequency estimation techniques as well as the comparison of all the three different methods. Section 2 is committed to the issues of parametric recurrence and range estimation to be tended to. The proposed method will be presented in Section 3. Reproduction results are exhibited in Section 4. At long last, conclusion is attracted Section 5.

2. Literature Survey

This section involves the survey of exiting researches in recursive frequency and spectrum estimation. Author Chen et al. [1] have executed an enhanced recursive minimum square (RLS) calculation was proposed to gauge time-differing AR parameters within sight of commotion. Interharmonics sign can be demonstrated as a nonstationary auto-backward (AR) show, the otherworldly estimation of inner harmonics sign can be given by the evaluated time-shifting AR parameters. AR parametric otherworldly estimation strategies have better recurrence determination. Nonetheless, the routine RLS calculation is delicate to the commotion, and settled overlooking component (FFF) has poor flexibility in the nonstationary environment. Another mean-squared-blunder (MSE) target capacity in light of fourth-request cumulant was presented in this paper, which can smother the Gaussian commotion. For evaluating the time-differing spectra of nonstationary signs utilizing variable overlooking component (VFF). The consequences of reenactment demonstrated that in the uproarious environment, this proposed technique could get the ghastrly estimation of time-fluctuating inner harmonics precisely.

The work of Zhang et al. [2] have introduced am recursive channel estimation approach based on versatile Kalman channel to measure the non-linear signals time-shifting range. The outcomes of the approach suggests that the estimator can offer superior

determination of the time-recurrence than traditional approaches of parametric range estimations.

Further, the computationally efficient model of Zhang et al. [3] gives the significant way of estimating the recursive recurrence/range and determining the nonlinear signals. The outcomes of the model described the higher penetration towards the estimation of VFFC-QRRLM than traditional approaches under both time-variant units of narrowband and broadband units with incautions units. This approach can be implemented in quality force checking, discourse examination and online deficiency discovery.

Xiaoming et al. [4] proposed another versatile estimator for direct grouping spread range (DSSS) signals utilizing fourth-arrange cumulant based versatile strategy is considered. The general higher-request insights may not be effectively connected in sign preparing with excessively complex calculation. In light of the fourth-arrange cumulant with 1-D cuts and versatile channels, a productive calculation is proposed to take care of the issue and is stretched out for nonstationary stochastic procedures. Keeping in mind the end goal to accomplish the precise parameter estimation of direct succession spread range (DSSS) signals, the initial step utilizes the changed fourth-arrange cumulant to lessen the processing multifaceted nature. While the second step utilizes a versatile recursive framework to appraise the force range in the recurrence space. On account of blocked signs without sufficiently extensive information tests, the estimator gives great execution in parameter estimation and white Gaussian commotion concealment. PC recreations are incorporated to support the hypothetical advancement with various sign to-commotion proportion conditions and recursive coefficients.

Jeong et al. [5] exhibited a novel clamor power estimation strategy given smoothed ghastrly minima following and subtractive blocking network for double channel discourse improvement. By consolidating phantom attributes of the boisterous blend signals with spatial invalid shaft shaping, clamor over-and under-estimation issue can be considerably alleviated.

Erkelens et al. [6] consider estimation of the ghastrly commotion difference from discourse signals sullied by very nonstationary clamor sources. For clamor control estimation, an otherworldly pickup capacity is utilized, which is found by an iterative information driven preparing technique. The proposed clamor the following strategy is tried on different stationary and nonstationary commotion sources, for an extensive variety of sign to-clamor proportions, and contrasted and two best in class techniques. At the point when utilized as a part of a discourse upgrade framework, enhancements in segmental sign to-commotion proportion of more than 1 dB can be acquired for the most nonstationary clamor sources at high clamor levels.

Zhang et al. [7] proposed to take care of the issue and reached out for non-stationary stochastic procedures. So as to accomplish exact parameter estimation of direct arrangement spread range (DSSS) signals, the initial step utilizes the changed fourth-arrange cumulant to diminish the figuring many-sided quality. While the second step utilizes a versatile recursive framework to gauge the force range in the recurrence space. For the instance of caught signs without sufficiently substantial information tests, the estimator gives great execution in parameter estimation and white Gaussian commotion concealment. PC reproductions are incorporated to verify the hypothetical advancement with various sign to-clamor proportion conditions and recursive coefficients.

The work of Tarvainen et al. [8] consists of a parametric approach of range estimation strategy for breaking down nonlinear heart rate signals. Initially, the nonlinear signal is demonstrated with time-variant fluctuating AR model and its evaluation is performed a Kalman smoother calculation.

Further, Khalilinia et al. [9] have explained the multi-dimensional approach of recursive computation by using frequency domain based decomposition (FDD). The performance of this approach is compared with general form of FDD approach used to estimate the Power Spectrum Density (PSD) estimation. The outcomes suggests that the proposed approach yields smoother PSD estimation than general FDD approach.

Bruno et al. [10] proposed a calculation for joint time-recurrence wideband range detecting in light of applying a type of transient range detecting together with a recursive tree look. The calculation can distinguish range openings precisely even within sight of blasting essential signs and essential flags whose force ghastry densities have smooth band edges. Numerical results are exhibited which demonstrate the execution addition of the proposed calculation over before ways to deal with wideband range detecting.

In the work of Glentis et al. [11] speedy computation approach of adequacy and stage estimation (APES) is proposed to examine the time variant signal analysis. The performance of computationally efficient approach is better than that of existing strategies. Here, the broadband signals were used to represent the execution of the proposed model outcomes.

Jeong et al. [12] introduced a novel commotion power estimation strategy in light of smoothed otherworldly minima following and subtractive blocking framework for double channel discourse improvement. By joining phantom qualities of the loud blend signals with spatial invalid pillar framing, clamor over-and under-estimation issue can be considerably alleviated. This commotion estimation process considers nonlinear clamor conditions beating other single-channel commotion estimation under minima following and double channel stage blunder based upgrade computation.

3. Proposed Method and Implementation

In this section discussed the implementation of the proposed method. It contains the input signal generator. This signal generator generates the signal based on the different frequency given to the system. Then applying the estimation techniques to this signal to calculate the root mean square deviation value. It uses the QRRLM, AD-VRR-GRRLS and AD-VRR-QRRLM method to calculate the root mean square deviation value. By applying the different method for different frequency signal, we will get different room means square deviation value. From this, we can observe that the AD-VRR-QRRLM method gives better spectrum for a given input signal. The room means square deviation is used as a performance parameter for this experiment. Fig 1 shows the design system architecture of the proposed method. It uses three different recursive frequency estimating techniques for analyzing the input signals. Table 1 also shows the notation used in this paper.

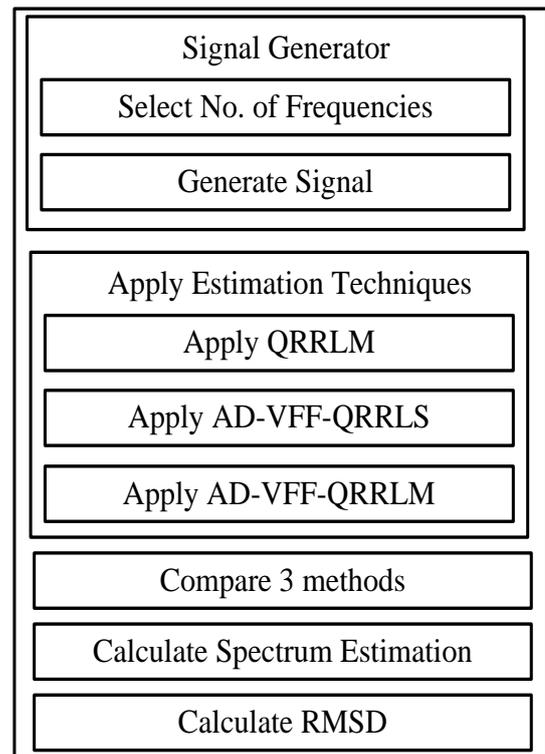


Fig 1. System architecture of the proposed method.

4. Research and Discussion

To validate the effectiveness of the proposed low-complexity distortion algorithm regarding spectral regrowth suppression, a general form of computationally efficient parametric mechanism based model is presented to estimate the recursive frequency/spectrum and describe the nonlinear signals which consists of diverse degrees of nonlinearity and and indiscreet units. The time variant frequency estimation is defined as the as a time-varying model recognizable proof issue in which faulty/failure data are evaluated by model coefficients. Fig 2 to fig 8 shows the results obtained in this simulation work of the proposed method. It uses three different methods for four different frequency to calculate the signal spectrum as well as root means square deviation values of the given input signal. Based on this value the best and better method is decided.

Table 1. Notation used in paper

QRRLM	QR-decomposition-based recursive least M-estimate.
VFF	Variable Forgetting Factor.
WT	Wavelet Transform.
AR	Autoregressive.
ARMAs	Autoregressive Moving Averages.
SNR	Signal-to-Noise Ratio.
AD-VFF-QRRLS	AD-Variable Forgetting Factor-QR-decomposition-based Recursive Least Squares.
AD-VFF-QRRLM	AD-Variable Forgetting Factor-QR-decomposition-based Recursive Least M-estimate.
RMSD	Root Mean Squared Deviation.
RRLM	R-decomposition-based Recursive Least M-estimate.

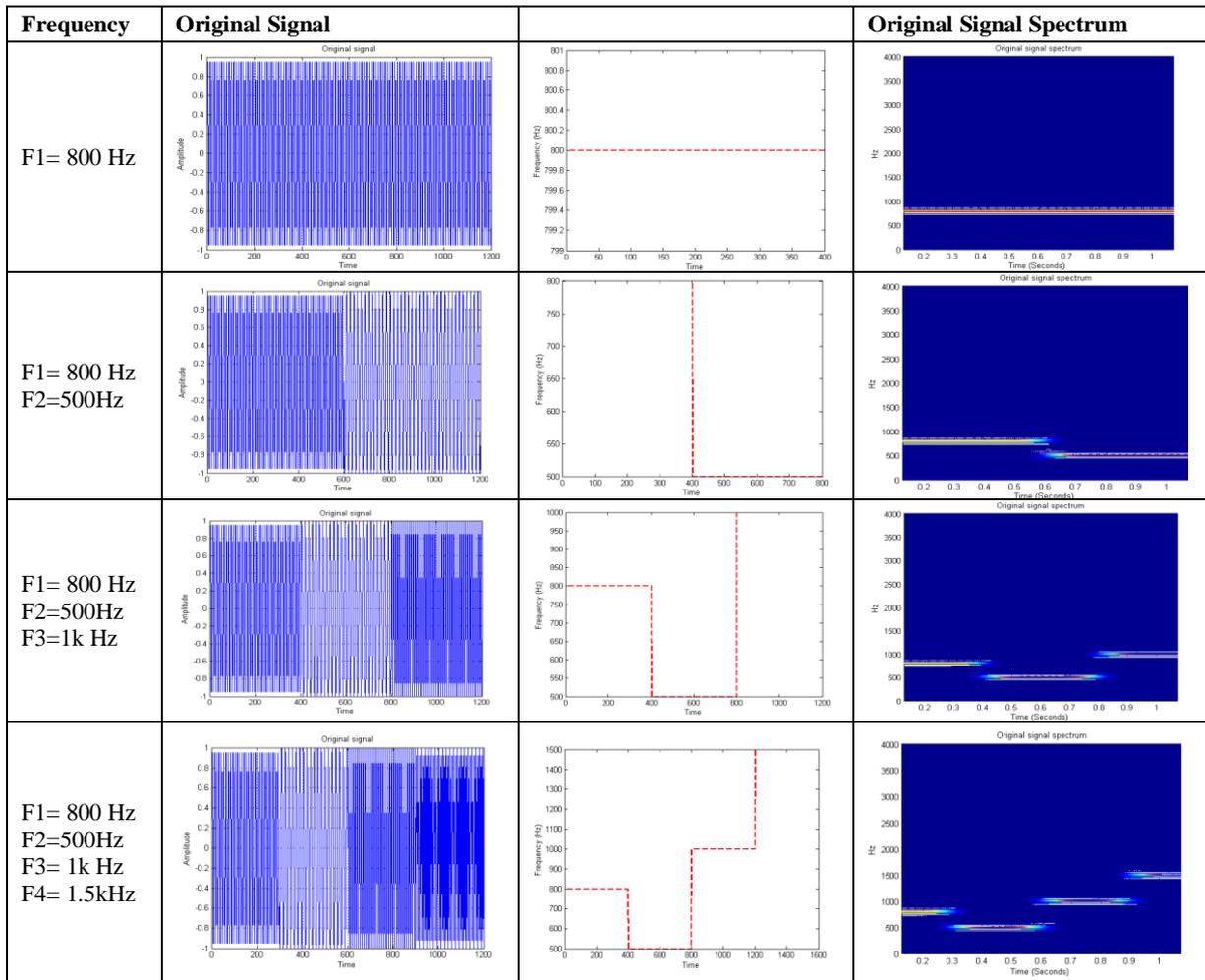


Fig 2. Original signal and signal spectrum for different frequencies

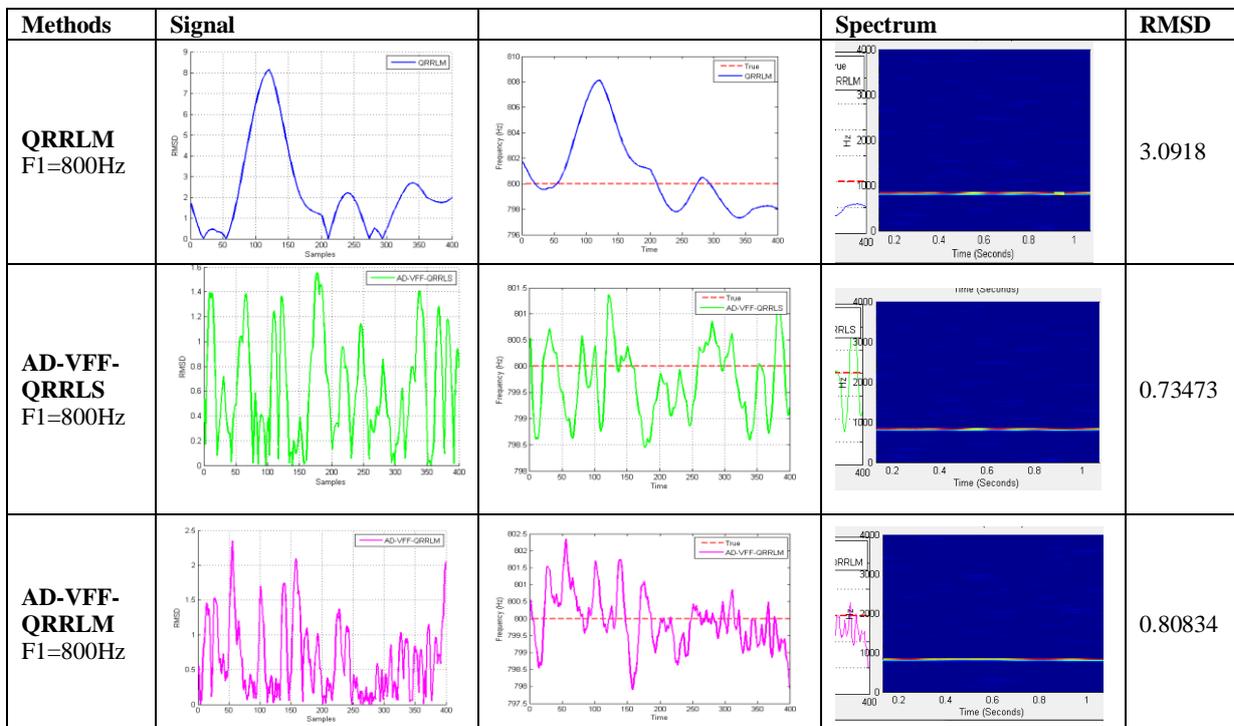


Fig 3. Original signal, signal spectrum and RMSD values for same frequency for different methods

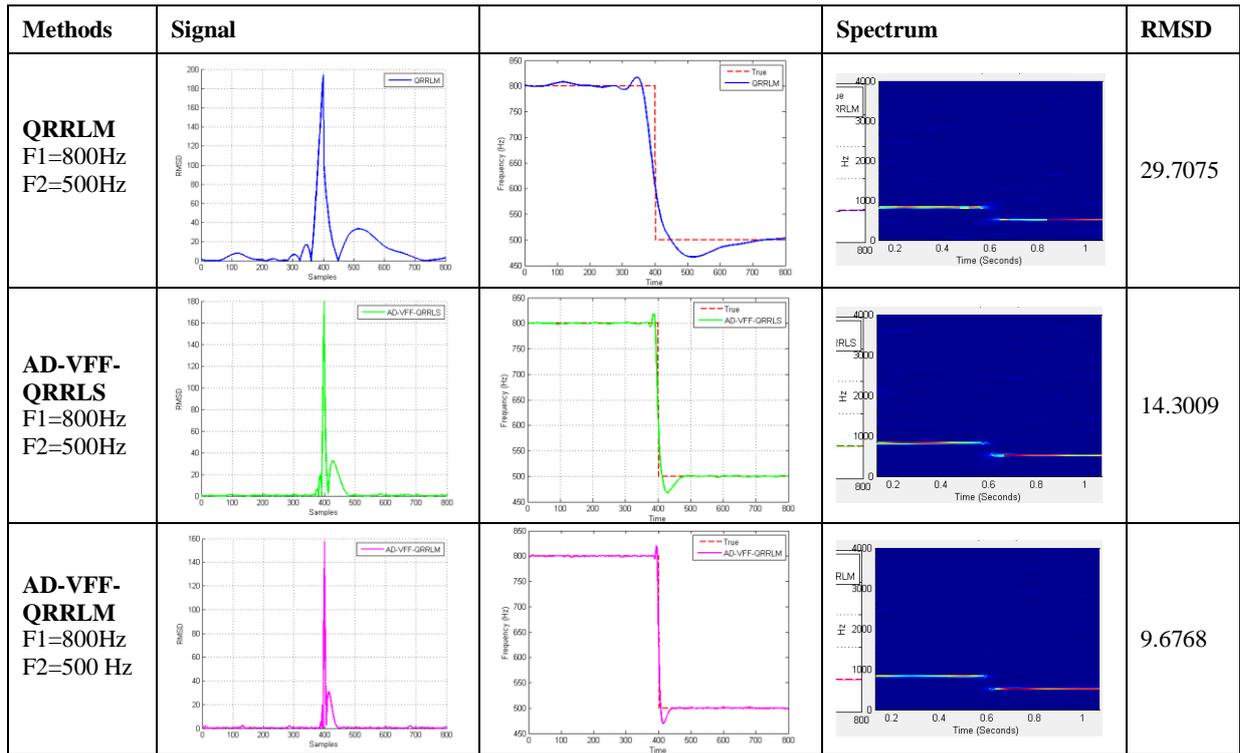


Fig 4. Original signal, signal spectrum and RMSD values for 2 different frequency for different methods

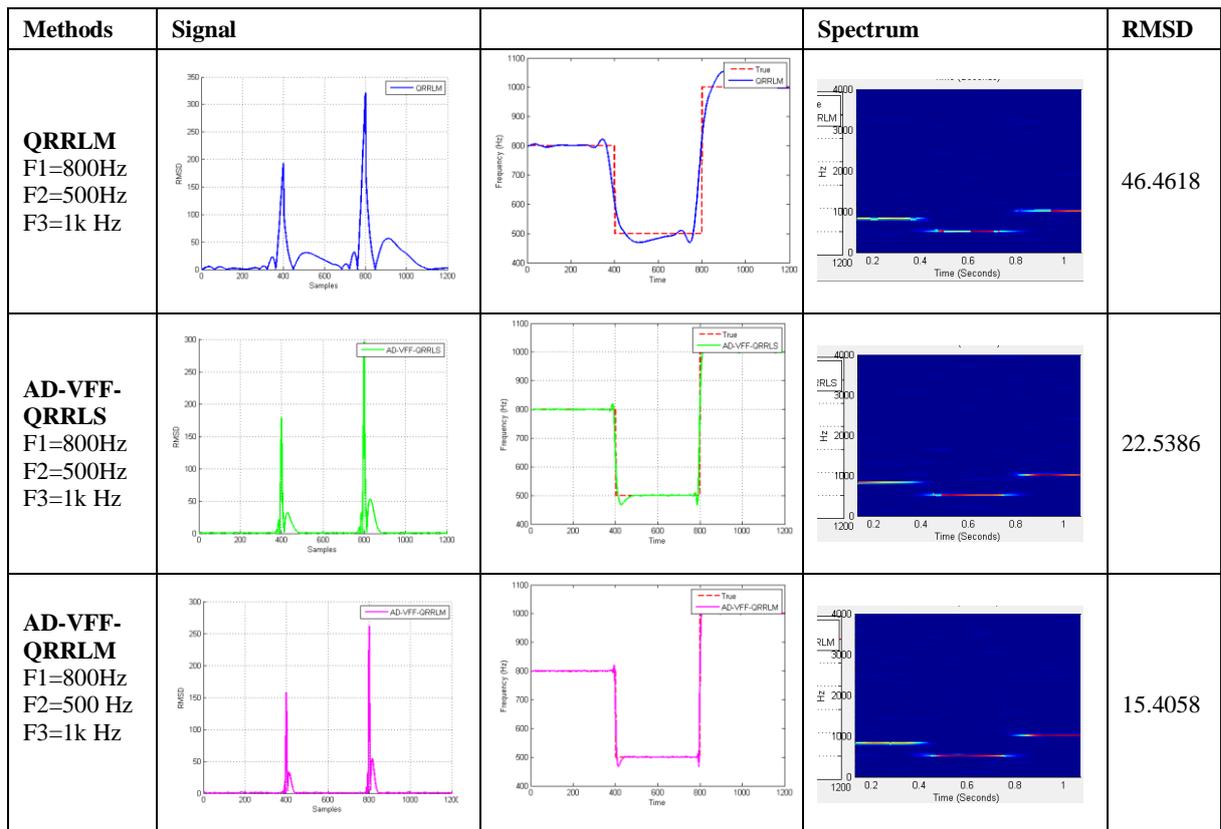


Fig 5. Original signal, signal spectrum and RMSD values for 3 different frequency for different methods

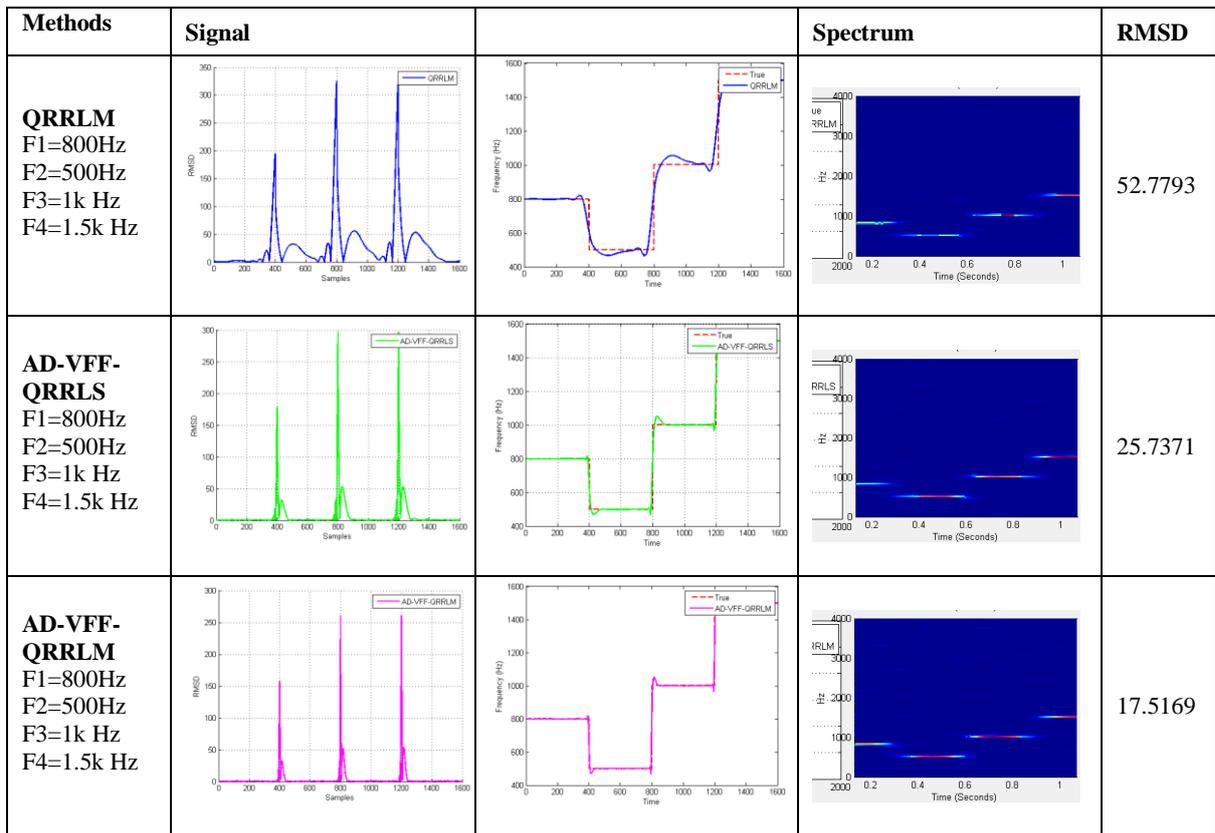


Fig 6. Original signal, signal spectrum and RMSD values for 4 different frequency for different methods

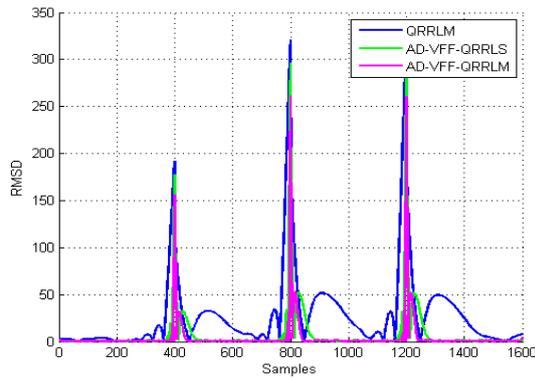


Fig 7. Comparison of RMSD values for different methods.

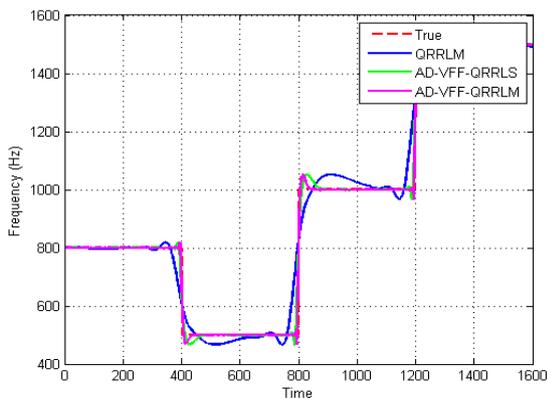


Fig 8. Comparison of Frequency estimation for different methods.

Table 2. RMSD values for same frequency for different methods.

Frequency	Methods	RMSD
F1=800 Hz	QRRLM	3.0918
	AD-VFF-QRRLS	0.73473
	AD-VFF-QRRLM	0.80834

Table 3. RMSD values for 2 different frequency for different methods.

Frequency	Methods	RMSD
F1=800 Hz F2=500 Hz	QRRLM	29.7075
	AD-VFF-QRRLS	14.3009
	AD-VFF-QRRLM	9.6768

Table 4. RMSD values for 3 different frequency for different methods.

Frequency	Methods	RMSD
F1=800 Hz F2=500 Hz F3=1k Hz	QRRLM	46.4618
	AD-VFF-QRRLS	22.5386
	AD-VFF-QRRLM	15.4058

Table 5. RMSD values for 4 different frequency for different methods.

Frequency	Methods	RMSD
F1=800 Hz F2=500 Hz F3=1k Hz F4=1.5k Hz	QRRLM	52.7793
	AD-VFF-QRRLS	25.7371
	AD-VFF-QRRLM	17.5169

Table 6. Comparison for RMSD values for different methods and also different frequencies.

RMSD	Methods	F1	F1, F2	F1, F2, F3	F1, F2, F3, F4
	QRRLM	3.0918	29.7075	46.4618	52.7793
	AD-VFF-QRRLS	0.73473	14.3009	22.5386	25.7371
	AD-VFF-QRRLM	0.80834	9.6768	15.4058	17.5169

5. Conclusion and Future Direction

This paper had introduced a computationally efficient parametric mechanism based model for estimation of recursive frequency and spectrum and describe the identification of nonlinear signals that

contrains the diverse degree of nonstationarities and indiscreet units. The time variant frequency estimation is defined as time variant model with recognizable proof issue in which evaluation of unhealthy data is performed by using model coefficients. The estimation of resultant ADVFFC-QRRMLM can confine and limits the speedy units while it deals with the various gastley varieties. The performance analysis gives that the estomation of VFFC-QRRMLM is robust and accurate than the existing recursive approach for estimation of both the narrowband time shifting units and broadband units with incausion parts. Potential uses of the proposed technique can be found in quality force checking, online deficiency location, and discourse examination.

References

- [1] H. Chen, Z. Wang, Y. Lu, D. Li and T. Li, "Cumulant-Based RLS Algorithm with Variable Forgetting Factor to Estimate Time-Varying Interharmonics," *Instrumentation and Measurement, Computer, Communication and Control (IMCCC), 2014 Fourth International Conference on*, Harbin, 2014, pp. 351-356.
- [2] Z. G. Zhang, S. C. Chan and X. Chen, "A new Kalman filter-based recursive method for measuring and tracking time-varying spectrum of nonstationary signals," *Information, Communications and Signal Processing (ICICS) 2013 9th International Conference on*, Tainan, 2013, pp. 1-4.
- [3] Z. G. Zhang and S. C. Chan, "Recursive Parametric Frequency/Spectrum Estimation for Nonstationary Signals With Impulsive Components Using Variable Forgetting Factor," in *IEEE Transactions on Instrumentation and Measurement*, vol. 62, no. 12, pp. 3251-3264, Dec. 2013.
- [4] Z. Xiaoming and Z. Zhongzhao, "Parameter estimation of DSSS signals in non-cooperative communication system," in *Journal of Systems Engineering and Electronics*, vol. 18, no. 1, pp. 14-21, March 2007.
- [5] S. Y. Jeong, K. Kim, J. H. Jeong, K. C. Oh and J. Kim, "Adaptive noise power spectrum estimation for compact dual channel speech enhancement," *2010 IEEE International Conference on Acoustics, Speech and Signal Processing*, Dallas, TX, 2010, pp. 1630-1633.
- [6] J. S. Erkelens and R. Heusdens, "Tracking of Nonstationary Noise Based on Data-Driven Recursive Noise Power Estimation," in *IEEE Transactions on Audio, Speech, and Language Processing*, vol. 16, no. 6, pp. 1112-1123, Aug. 2008.
- [7] X. m. Zhang and Z. z. Zhang, "Parameter Estimation of DSSS Signals with Line Enhancement," *2006 IEEE International Conference on Information Acquisition*, Shandong, 2006, pp. 127-132.
- [8] M. P. Tarvainen, S. Georgiadis and P. A. Karjalainen, "Time-Varying Analysis of Heart Rate Variability with Kalman Smoother Algorithm," *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference*, Shanghai, 2005, pp. 2718-2721.
- [9] H. Khalilinia; V. Venkatasubramanian, "Recursive Frequency Domain Decomposition for Multidimensional Ambient Modal Estimation," in *IEEE Transactions on Power Systems*, vol. PP, no.99, pp.1-1.
- [10] J. M. Bruno and B. L. Mark, "A recursive algorithm for joint time-frequency wideband spectrum sensing," *Wireless Communications and Networking Conference Workshops (WCNCW), 2015 IEEE*, New Orleans, LA, 2015, pp. 235-240.
- [11] G. O. Glentis, "Efficient Algorithms for Adaptive Capon and APES Spectral Estimation," in *IEEE Transactions on Signal Processing*, vol. 58, no. 1, pp. 84-96, Jan. 2010.
- [12] S. Y. Jeong, K. Kim, J. H. Jeong, K. C. Oh and J. Kim, "Adaptive noise power spectrum estimation for compact dual channel speech enhancement," *2010 IEEE International Conference on Acoustics, Speech and Signal Processing*, Dallas, TX, 2010, pp. 1630-1633.