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Energy based signal parameter estimation method and a comparative study of different frequency estimators

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ABSTRACT

The influences of window functions and noise on the performance of the energy-based signal parameter estimation method are investigated, and the appropriate parameters and algorithm are recommended accordingly. The frequency, amplitude and phase estimation variances of the energy based method are deduced and verified by computer simulation. The performances of four frequency estimation methods are compared: the energy based method, the interpolation based method, the phase difference based method and the Fourier transform (FT) continuous zoom based method. For the second and third methods, the Quinn algorithm and the phase difference based method with factor $\eta=0.5$ are recommended, respectively. It was found that each method has its own advantages. The energy based method has the best stability compared with others. The interpolated method has the lowest frequency estimation variance when the frequency biasδ is large, while the phase-difference based method does better when δ is low. The change of δ does not influence the maximum frequency estimation error of the FT continuous zoom based method. Comparatively speaking, the phase-difference based method has the least frequency estimation error.

1. Introduction

The estimation of the frequency of a single sinusoidal signal (or a multi-frequency signal with a large frequency distance) in white Gaussian noise is relevant to a wide range of applications, such as radar, sonar, communications, etc., and has consequently received significant attention. The parameter estimation problem was initially formulated by Slepian [1], and his works mainly concentrated on the continuous-time observation model. In the cases of discrete-time observations, the Cramér–Rao (CR) bounds of estimation error and the maximum likelihood (ML) estimators of the signal parameters were examined and developed by Rife and Boorstyn in [2]. After that, CR bounds became the performance evaluation criteria of any other frequency estimator used as a substitute of ML estimator. Although the ML estimator can achieve the CR bounds at signal-to-noise ratios (*SNR*) of practical interest, the algorithm is complicated and very time-consuming. Several simpler frequency estimation methods have been developed in recent decades. Those methods can be grouped into four classes: the interpolation based method, the phase difference based method, the energy based method and the FT continuous zoom based method. Among all these methods, the interpolation based method is most popular, and strategies with different expressions are presented for signal parameters estimation [3–10]. The commonly used interpolated algorithms include the Rife–Jane algorithm and the Quinn algorithm. The noise influence on the accuracy of this method was studied by Schoukens et al. [7] qualitatively and by Offelli and Petri [8] quantitatively.

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