Comparative Analysis and Evaluation of Common Spectrum Correction Methods

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Abstract. Although there are many spectrum correction theories and implementations, they are individual to specific problem and lack of a comprehensive comparison. This brings down their practical value in engineering applications. To solve this problem, we hereby establish a spectrum analysis and correction system. Each method i.e. Energy BaryCenter Method, Ratioing, Phase Difference Method, Continuous Zoom and All-Phase Spectrum Analysis. Meanwhile summarizing their accuracy,universa lity,practicability and window function. Then, we obtained a comprehensive assessment of all kinds of methods and created reference value for practical engineering application.

Keywords: frequency analysis, frequency spectrum correction, evaluation system.

1. Introduction

During the digital signal processing, as the computer can only calculating for finite sample. Both Fourier transform and spectral analysis are focusing on analyzing the time domain truncation signal. Energy leak will happen when it comes to time domain truncation, and it makes the peak of frequency spectrum decreased, phases deviated, and precision reduced. Spectrum magnitude, frequency, and phase are not work at the application in the practical engineering even with the method of windowing. Thus we need to revise the amplitude, frequency, and phase of frequency spectrum. Common spectrum correcting methods can be divided into five kinds including all phase spectrum correction method found recent years: Firstly, Energy BaryCenter Method[1][2]. Secondly, Ratioing [3]. Thirdly, Phase Difference Method [4]. Fourthly, Continuous Zoom [5][6]. Fifthly, and All-Phase Spectrum Analysis [7][8].

Some of the existing theory and application of spectrum correction methods are mature. They also have some research achievements in different ways of comprehensive analysis. As early as 2000, Kang Ding

and Xiao-fei Zhan made a summary on the theoretical development of spectrum correction [11].In 2001, Xiao-yong Zhu and Kang Ding published Comprehensive Comparison of Discrete Spectrum Correction Method [6]. In 2006, Xiang-dong Huang made a summary based on all phase thought energy center of gravity method, the all phase ratio method and all phase method of phase difference correction method [18]. In 2008, Kang Ding, Ming Xie, and Zhi-jian Yang sorted out the updated theory and technology from the Discrete Spectrum Analysis and the Correction Theory and Technolory. In 2012, Yu-wen Mao, Ya-qing Tu, Wei Xiao, and Hui-yue Yang Aimed at the research progress in discrete density frequency room analyzing and correction method made a conclusion. Comprehensive comparison and analysis results we have thorough concluded from the proposing of existing spectrum correction method theory to mature, as well as the induction of technology. However, as the diversity, particularity, and pertinence of spectrum correction method, technician needs to analyze a certain number of parameters even through probation to ensure the exact spectrum correction method at the application in the practical engineering. The comprehensive comparison of pure theory and technology can't meet engineering application personnel's need. To solve it, we should found a set of assessment system which has practical reference meaning in engineering application that based on several common correction methods of parameters such as accuracy, applicability and feasibility. It has practical significance to engineering personnel when they make quickly judge and select at the appropriate spectrum correction method according to the comparative analysis and evaluation of different spectrum correction method.

2. Comparison and analysis of common spectrum correction method

2.1 Energy BaryCenter Method

Energy BaryCenter Method is a universal correction method, which is through the use of various window functions, the characteristics that the infinite approximation of the discrete spectrum of origin energy center of gravity to make the discrete spectrum correction, and suitable for the frequency of the practical engineering applications of small fluctuations. The main parameters of the energy center of gravity method: the type of window function, the signal to noise ratio and the normalized frequency deviation, and the correction points.

2.2. Ratioing

Using the window spectrum ratio that near the main lobe peak signal of the two lines, which is namely that the ratio of the maximum amplitude of the main valve Ak and sharp value of Ak'(k'corresponds to the spectral line numberAk'), to establish a normalized frequency correction which is based on the variable equation, and then solving the, and making frequency, amplitude and phase correction. The amplitude accuracy obtained by the ratio correction method is still very high. The main parameters that affect the calibration accuracy of the ratio method: signal to noise ratio, frequency correction, window function type, etc.

2.3. Phase difference Method

The method is through the time shift and the addition of different symmetrical windows for the twice FFT analysis, and the use of discrete spectrum corresponding to the phase difference of the peak spectral line to get the frequency and phase correction. On the FFT analysis of two time domain sequences with different window functions as N points and M points, the time domain frequency shift length is L, according to N, M, and L can be divided into two kinds of phase difference method in time domain translation and change

window length method. The main parameters that affect the correction accuracy of the phase difference method: the time domain translation length L, the frequency spectrum analysis, the interception length N and M, the window length, and the window function type.

2.4. Continuous Zoom

In a wideband signal, the narrow band signal is analyzed in a frequency domain, and using FFT to estimate the spectrum of the signal, obtained the detailed range of narrow band spectrum; aiming at the locality that needed to refine to use the continuous improvement of the FFT to make operation, so as to get a local refinement of the high accuracy of the spectrum. This method can greatly improve the frequency resolution and improve the accuracy of the amplitude and phase of the sampling length without increasing the sampling length. The main parameters affected the accuracy of spectral continuous refining method of correction: the thinning ratio and the frequency resolution.

2.5. All- phase spectrum Analysis method

The all phase idea refers to the FFT spectrum analysis in the time domain not only considers a kind of input signal segmentation; it can be included in the FFT spectrum analysis and has a very good inhibitory spectral leakage performance and "phase invariance", widely used in the spectrum analysis of the spectrum with high accuracy requirements of the spectrum analysis. The main parameters affected the accuracy of all phase spectrum correction: the sampling points, the window function type, and the size of the added noise.

2.6. Comparative analysis

The energy center of gravity method, the ratioing, phase difference method is generally used to contain a single frequency component or the spacing between the larger multiple frequency components of signal of discrete spectrum correction method; continuous zoom of Fourier transforms, all phase spectrum analysis is generally used to contain multiple dense frequency component of the discrete spectrum correction method. On the intervals of larger multiple of the frequency components of the signal discrete spectrum correcting methods and more intensive frequency components of a signal correction method for discrete spectrum to compare the advantages and disadvantages of the two types and illustrated in table 1, table 2.

Table. 1 Discrete spectrum correction method to deal with the signal that Interval is larger and has multiple frequency components

	Advantage	disadvantage
Energy BaryCenter Method	Directly correction multi average power spectrum, Simple Algorithm, Compute fastly , Small errors on the accuracy, Correction method for a variety of symmetrical window function	Correction accuracy related to the window function. For too dense frequency spectrum, analysis accuracy is not high
Ratioing	Suitable for all symmetrical window function, High correction accuracy, This method is suitable for general engineering and signal processing	We need to know the spectrum mode functions Also not suitable for dense frequency component spectrum analysis

| Phase difference | Good commonality. Do not need to obtain the modulus of the window function. Can achieve precise correction of signal's frequency and phase, high correction accuracy | If the frequency components are very close, it will affect the accuracy of the correction even cannot be corrected |

Table. 2 Discrete spectrum correction method to deal with the signal that has
More intensive frequency components

	Advantage	**disadvantage**
Continuous Zoom	After refinement output spectrum frequency resolution is increased, peaks separate and clear, the trends same as the spectrum that near the original center of the spectrum	Computationally intensive
All- phase analysis method	Full phase correction method is suitable for the case of distant intervals and dense spectrum, especially for dense spectrum	Applications of immature

3. Assessment spectrum correction methods

For spectrum correction analysis, there are three major indicators, accuracy, reliability and universality. Accuracy shows observations, calculated, closeness between estimated value and true value. There are factors that affect the accuracy of Noise size, SNR, Normalized frequency deviation, Refinement multiples, The number of sampling points, The size of negative frequency[17] Reliability shows that whether to implement a spectrum correction method relies on the condition easily and accurately obtain, general digital signal processing dependent on hardware requirements. To consider the complexity and computation of the signal processing algorithms, if some kind of spectral analysis's operation is too big. In practical engineering applications, if hardware conditions cannot support a large amount of computation, the practical application is restricted. Universality shows some spectral correction method can be widely applied in similar engineering applications, spectrum correction method widely used in various dynamic signal analyzer and computerized testing system, analysis of rotating machinery vibration signals, Analysis of torsion vibration signal like engine. High precision frequency and amplitude calibration system. But in a certain type of application various methods has its own advantages, practical application needs to take all factors, compare and analyze various spectral correction methods, all factors of the various spectral correction methods were compared, or according to the results of the correction accuracy of the method you choose after use directly. But affect the efficiency and practical value. Analyze the universality of various spectral correction method can provide reference for practical engineering application. Current correction method areas can be divided into vibration, voice, image and noise. In the windowing processing, there are some commonly used window function like Rectangular window, Hamming window, Hanning, Blackman and so on. Different window functions has a great impact on the quality of the spectral function in the signal processing, Therefore, select Window function is particularly important in the signal processing. So it can be summarized in Table 3. Details are as follows：

Table. 3 Evaluation system

First-level indicators	Secondary indicators
Accuracy	Noise resistance
	Deviation of normalized frequency
	Refinement multiples
	Affection of sampling points
	Contribution of negative frequency
	Affection of energy coefficient
	Affection of MSE e
	Affection of frequency resolution
	Affection of input SNR
Reliability	The difficulty of hardware implementation
	Algorithm complexity
	Computation
Universality	Applicability of mechanical vibration
	Applicability of speech signal processing
	Applicability of image processing
	Applicability of denoising system
Window function	Affection of window function type
	Affection of the window function n
	Affection of Window length
	Affection of time-domain translation + change in length

Using a simple four-level evaluation method is excellent, good, fair, and poor to evaluate the system. No need to refer all secondary indicators.

4. Conclusion

The System is based on theoretical basis of various spectral correction methods to undertake a comprehensive induction. Energy BaryCenter Method, Ratioing, Phase Difference Method, Continuous Zoom and All-Phase Spectrum Analysis that signal's frequency component has a larger interval. Spectrum analysis of continuous refinement and all phase spectrum correction method applies for the discrete spectrum correction that signals has multiple intensive frequency components. This article compares the advantages and disadvantages of various methods of correction, meanwhile summarized the critical parameter index that affect the accuracy of each spectrum correction method. We designed an evaluation system from four aspects. According to the assessment system design methodology, Accuracy, Reliability, Universality and Window function as a first-level metrics. On this basis, Split first-level indicators into specific secondary indicators. In practical applications, assess some kind spectrum correction method, then according to the secondary indicators and scoring screening, finally, determined the most appropriate spectral correction method.

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