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Fast Characterization of Frequency Response in High-Speed Signal Generators with Frequency-Interleaving Technique

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SUMMARY This paper presents a frequency interleaving method to correct non-ideal characteristics of wideband signal generators. By effectively segmenting a discrete Fourier transform dataset into frequency-interleaving blocks, the proposed method is computationally more efficient than the conventional method based on Fast Fourier Transform (FFT). In cases the quality of frequency analysis can be improved by zero padding such as characterizing impulse responses, this method is effective because it is possible to interleave two or more FFT results to achieve better frequency resolution. To verify the proposed method, an arbitrary signal generator was tested with a 64 quadrature-amplitude-modulation waveform. Compared with the original signal quality, the proposed method improves the in-band signal-to-noise ratio by 9 dB, and the error-vector magnitude decreases from 2.1%$_{rms}$ to 0.78%$_{rms}$. In all cases, the computation speed was faster than that of conventional FFT.
key words: *Error Vector Magnitude, Discrete Fourier Transform, Fast Fourier Transform, Quadrature Amplitude Modulation*.

1. Introduction

With the evolution of communication technologies, methods for the precise measurement, analysis, and correction of high-speed systems are increasingly necessary [1]-[4]. Analysis and correction are predominately performed in the frequency domain using the discrete Fourier transform (DFT) and the fast Fourier transform (FFT) [1],[3]. Despite the popularity and versatility of these methods, DFT and FFT analyses contain artifacts such as picket fence effect, and discreteness in their spectral content. These artifacts result from practical limitations regarding the limited spectral resolution of the captured waveform [4],[5].

Moreover, the minimum sampling requirement in the measurement system becomes unacceptably high because of the wide bandwidth of the latest communication devices [6]. Therefore, more waveform samples must be captured for a given time duration; otherwise, the spectral resolution of the signal becomes coarse because of the discrete nature of the FFT [7],[8]. To increase the resolution of the spectral components, two methods are commonly adopted: interpolation and zero padding. Interpolation takes adjacent spectral samples to estimate the discrete time Fourier transform (DTFT) local peaks. However, the interpolation function may introduce additional noise to the spectral information [9].

On the other hand, given that the captured dataset

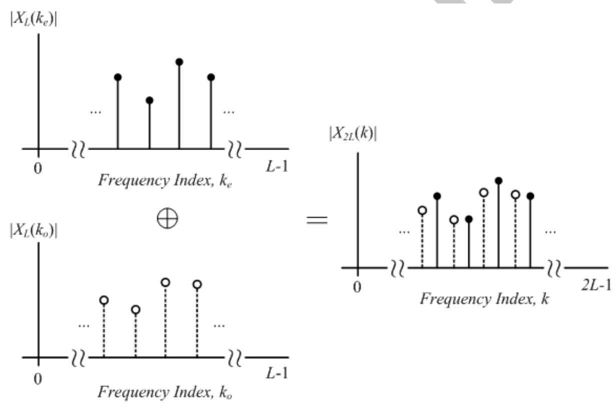

Fig. 1 Frequency interleaving of two L-sample DFT results to compose a 2L spectral dataset.

includes necessary waveform information, zero padding followed by FFT can provide accurate positioning of spectral components, while leaving the spectrum leakage and signal-to-noise ratio unchanged. However, the increased data length places an exponential burden on the signal processors. To date, research has suggested efficient FFT pruning methods that simplify the process by skipping paths in the transform that incorporate zero inputs. However, these methods deal with cases when the data length is radix-2, redefine complex transform algorithms, or sacrifice accuracy for speed [10]-[12].

In this paper, we consider cases where zero padding is a valid method to increase the resolution of spectral analysis (such as the characterization of impulse responses with multisines), and propose an interleaving technique for FFT data vectors of any length to compose a fine-resolution FFT result. Being equivalent to zero padding, the proposed method provides better in-band signal quality by revealing a spectral quantity otherwise hidden by the discrete nature of the FFT. In particular, the system response of wideband signal generators achieves better accuracy with this method, because its impulse response is time limited. In addition, this method is efficient because unnecessary calculations with zeros are eliminated.

In the following section, a mathematical approach for the interleaving is presented. The signal quality and computing efficiency are then verified in Section 3 and 4. An experimental correction result with an arbitrary signal generator is presented as a practical application of

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