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A Real-Time Spectrum Sensing Method by Averaging Spectra of Finite-Time Fourier Transform

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1 Extended Abstract

Spectrum observation/sensing is one of the important issues in radio communication systems. Those systems normally use DFT (discrete Fourier transform) where the input signal is extracted from the original one with a finite time window. However, the observed spectrum is to have false frequency components, what is said *spectrum leakage*, due to its finite time window. Some countermeasures are known, overlapped FFT, extending the window length, for example [1]; increase of computation complexity or degrade of frequency resolution becomes a problem. The authors of this paper proposed a new spectrum measurement method to obtain a high frequency resolution with a low computation load and the basic idea and principles are shown in [2] with computer simulations. In this paper, the principle of the method why the *leakage* is suppressed and the basic properties are shown with theoretical analysis.

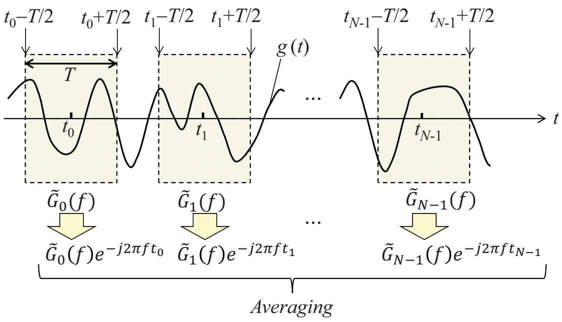

Figure 1. Fourier transform with time-shift windows.

Figure 1 illustrates the proposed processing of Fourier transform. It averages each the DFT or finite-time Fourier-transformed spectrum after the phase rotation corresponding to the time difference of each the observation window. Let $g(t)$ and $\tilde{G}_n(f)$ respectively be the input time domain signal and the spectrum normally obtained from the n-th observation window assuming $t_n = 0$, the averaged spectrum can be expressed with the phase rotation as

$$\hat{G}_N(f) = \sum_{n=0}^{N-1} e^{-j2\pi f t_n} \tilde{G}_n(f), \text{ where } \tilde{G}_n(f) = \int_{-T/2}^{T/2} g(t_n+\tau)e^{-j2\pi f\tau} d\tau = e^{j2\pi f t_n} \int_{t_n-T/2}^{t_n+T/2} g(t)e^{-j2\pi f t} dt \ , \quad (1)$$

and T is the window length. In case $t_n - t_{n-1} = T$, (1) is written as $\hat{G}_N(f) = \int_{t_0-T/2}^{t_{N-1}+T/2} g(t)e^{-j2\pi f t} dt$. Note that the spectra $\hat{G}_N(f)$ and $\tilde{G}_n(f)$ can be obtained only at the discrete M frequency points $f = m/T$, $-M/2 \leq m \leq M/2-1$ where M is the number of DFT points and even. It can be seen that $\hat{G}_N(f)$ gives a good approximation of the spectrum of $g(t)$, that the *spectrum leakage* can be suppressed, and that the frequency resolution becomes improved at each the frequency point as long as the most of the energy of $g(t)$ is within the extended interval $(t_0 - T/2,\ t_{N-1} + T/2)$. However, the number of frequency points is still M and does not becomes NM.

References

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[2] M. Ohta, M. Taromaru, T. Fujii, and O. Takyu, "Study on false alarm probability reduction method using FFT for spectrum sensing to unknown signals," *IEICE Technical Report*, **115**, 411, SR2015-79, pp. 51–56, Jan. 2016 (in Japanese).