Short-time Fourier Transform with Adaptive Window Sizing for THz-TDS

Jun Song[1,2], Sebastian Engelbrecht[3], Bernd M. Fischer[3], Hungyen Lin[2]
[1] Department of Information Science, Nanjing Forestry University, Jiangsu Province, 210037, China
[2]Department of Engineering, Lancaster University, Lancaster LA1 4YW, United Kingdom
[3]French-German Research Institute of Saint-Louis, Saint-Louis, 68301, France

***Abstract*— An adaptive windowing short-time Fourier transform algorithm is proposed where the width of short-time window is adaptively adjusted based on the frequencies of interest. The algorithm is then applied to lactose measurements acquired using THz-TDS and compared against the standard fixed window STFT spectrogram where improved contrast can be observed.**

I. INTRODUCTION

SHORT-Time Fourier Transform (STFT) have been proposed as a means to obtain depth resolved frequency information. For example, STFT was employed in [1] to identify spectroscopic information of coated pharmaceutical tablets. Standard STFT was introduced in [2] to perform experiments on the analysis of terahertz-pulsed imaging data. STFT based on a shifting fixed-width window was used in [3] to efficiently denoise THz-TDS measurements, and several different windows with fixed size were cited to construct parameter extraction algorithms which were utilized to process the lactose transmission THz-TDS data for accurate parameters estimation.

One of the limitations to date is the fixed window size used in STFT, which results in a reduction of spectral resolution according to the Heisenberg-Gabor inequality. To overcome this restriction, we propose an adaptive windowing STFT algorithm where the window size is adaptively adjusted based on the frequencies of interest. The improved time-frequency analysis in turn allows an efficient computation of the time-domain data and can reveal the spectral information otherwise not evident when processed with a fixed window STFT.

A standard STFT for processing signal x(t) can be defined as:

$$STFT(t,f) = \int_{-\infty}^{+\infty} x(\tau) g(t-\tau) \exp\left(-j2\pi f \tau\right) d\tau$$

here g is a Gaussian window and given as:

$$g(t) = 1 \Big/ \sqrt{2\pi}\sigma \exp\left(-t^2 \Big/ 2\sigma^2\right)$$

where σ^2 is the variance.

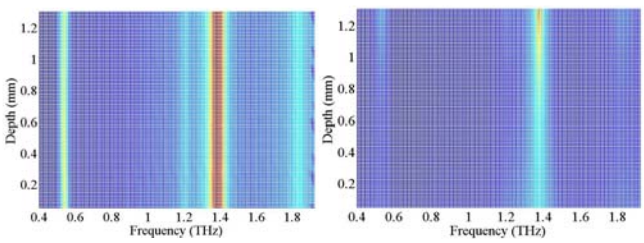

Fig.1 Comparison of the spectrograms for lactose sample when processed using the proposed algorithm and standard fixed window STFT

II. RESULTS

In the proposed algorithm, the Gaussian window size is adaptively optimised based on the smallest frequency component of interest, which can be obtained by performing a FFT of the entire waveform. Where there is no frequency found in the window, the window size will double to include more samples. The depth-frequency signature of lactose sample processed using the proposed adaptive windowing STFT is shown in Fig. 1, for comparison against the same measurement but processed using standard fixed window size STFT, where frequencies such as 0.53 THz becomes notably more evident. Even though in principle a fixed window STFT could be used with different window sizes to achieve similar results, the proposed algorithm is advantageous in that it offers an integrated approach thus increasing computational efficiency for effective signature identification.

III. ACKNOWLEDGEMENT

JS acknowledges the support from the Jiangsu Overseas Visiting Scholar Program for University Prominent Young & Middle-aged Teachers and Presidents. HL acknowledges the financial support from UK Engineering and Physical Sciences Research Council Research Grant EP/R019460/1.

REFERENCES

[1]Yao-Chun Shen, Philip Taday, “Development and application of terahertz pulsed imaging for nondestructive inspection of pharmaceutical tablet”, *IEEE Journal of Selected Topics in Quantum Electronics*, vol.14, no.2, pp. 407 – 415,2008.

[2]E. Berry, R.D. Boyle, A.J. Fitzgerald, J.W. Handley, “Time-Frequency Analysis in Terahertz-Pulsed Imaging in Computer Vision Beyond the Visible Spectrum”, *Bhanu B., Pavlidis I. (Eds).* London, UK: Springer, 2005, pp 271-311.

[3]M. Drouaz, S. Engelbrecht, L. Merlat, B.M. Fischer, B. Colicchio, A. Dieterlen, “Time-Frequency Filtering Applied to Terahertz Time-Domain Spectroscopy”, *41th IRMMW-THz*, pp. 1-4, Copenhagen, Denmark , Sept. 25-30 2016.

[4]José Vázquez-Cabo, Pedro Chamorro-Posada, Francisco Javier-Fraile-Peláez, Óscar Rubiños-López, José María López-Santos, PabloMartín-Ramos, “Windowing of THz time-domain spectroscopy signals: A study based on lactose”, *Optics Communications*, vol.366, no.5, pp. 386-396, 2016.