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Simulated Verification for a Finite Rate of Innovation Method Applied to Terahertz Signals

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***Abstract*—Methods utilizing finite rate of innovation theory have been employed to achieve low sampling rates in ultrasound experiments. Here, we apply this theory to create a terahertz specific method to gain the benefits of faster signal processing speeds and data acquisition compared with current standard processing methods. We verify our method by simulating a THz like signal, adding Gaussian noise, using a low sampling rate, processing it through our code and then comparing the reconstructed output to the original simulated signal to find close agreement.**

I. INTRODUCTION

FINITE rate of innovation (FRI) methods have been employed for efficient processing using low sampling rates in ultrasound experiments [1]. FRI applies to signals which have a finite number of degrees of freedom per unit time [2], which is applicable to both terahertz (THz) and ultrasound signals. The key benefit of methods utilizing FRI is the effective locating of the reflection positions and amplitudes whilst requiring relatively few data points to do so. In addition to faster signal processing speeds with lower sampling rates, many experimental set ups would gain faster data acquisition speeds with this method. For example, in THz time-domain spectroscopy a time delay line is moved along in steps, the number of which could be minimized with lower sampling rates. Benefits of faster data acquisition are especially useful in biomedical *in vivo* imaging, where for example in [3] patients must ensure their arms remain in the same position during the scanning process, which will be easier to achieve over shorter durations this method could provide.

II. RESULTS

In this work, code utilizing the FRI theory was verified by applying it to a simulated THz data set and comparing the reconstructed output to the original simulated signal input. This data set was created by modelling the THz pulse with a hamming windowed sum-of-sincs approximation, then randomizing the amplitude and time position of five modelled pulses to simulate a stratified medium. The randomization varied the magnitude of the largest amplitude of the pulse between 1.5 and 2.5 arbitrary units with the same factor applied to the rest of the pulse, and its time varied across the whole arbitrary axis. This generated signal had Gaussian white noise added to it, to achieve a signal-to-noise ratio of 5 dB, then under sampled to approximately four data points per waveform and finally ran through the code to recreate the original signal. The method calculates the time location and amplitude of each reflection, which can then be used to recreate the full signal as the pulse shape is known. Required foreknowledge includes the number of reflections or pulses expected, an additional requirement compared to many other signal processing methods commonly used in THz, however the code can be run multiple times with different estimations for the number of reflections until a sensible output is received for cases where the estimation is not precisely known.

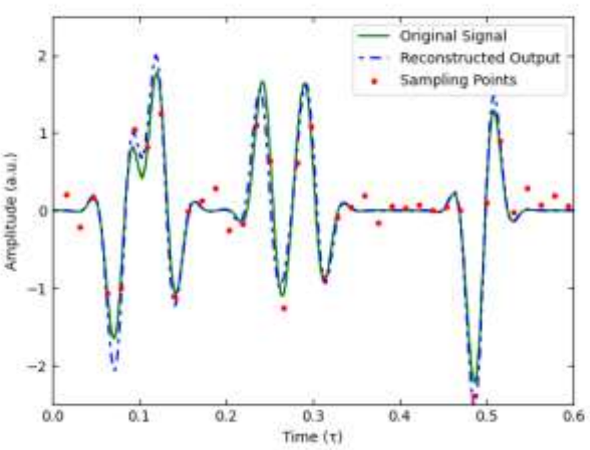

Fig. 1. The original simulated signal is shown by the green line, with the reconstruction after the application of our FRI method being shown with the dashed blue line. The low sampling of the simulated THz signal used in the method, with the addition of white Gaussian noise, are indicated by the red points.

Figure 1 shows the original simulated signal, the under sampled version with noise in points and the reconstruction of the original signal after the under sampled version has been processed through the FRI code. It can be clearly seen that the reconstruction closely matches the original signal, even with the relatively few sampling points used, thus faster processing speed achieved. This includes the first two pulses, where there is significant overlap between them, demonstrating that this method is able to resolve closely positioned reflections. As relatively large noise levels have been used in this simulation, with the original noiseless signal being recovered, it demonstrates that our method would perform well in expected experimental noise levels.

To conclude, this work verifies our FRI method applied to THz signals by comparing the reconstructed output to the original signal. We propose that our method could be implemented experimentally for efficient processing of THz signals, with the further benefit of faster data acquisition in certain experimental set ups.

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