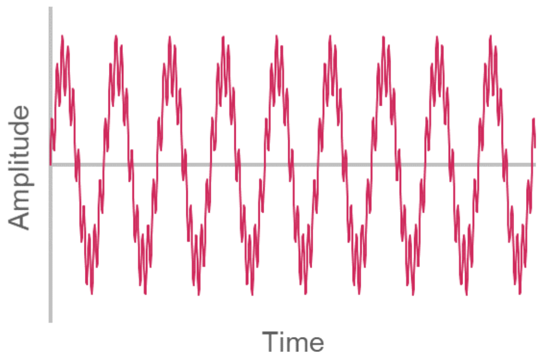
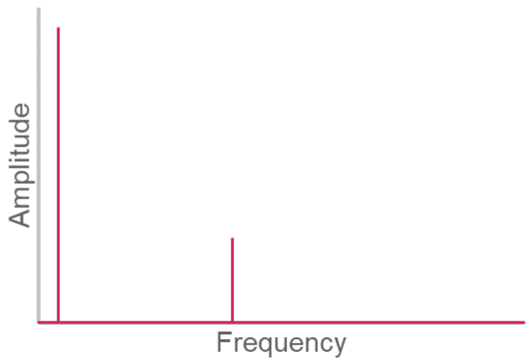
Alternate Transforms for Signal Processing

Background

Traditionally Fast Fourier Transforms (FFT) have been adopted for signal processing due to their computational efficiency in processing. The FFT is well known to convert received signals between the time and frequency domain and this conversion process is a common requirement in a wide variety of wireless systems. For example, the FFT allows us to easily extract the frequency information in the example below. The waveform shown on the left hand side is a sum of two sinusoids (perhaps a signal and some noise). The FFT recovers the information about the frequency and amplitude of the two sinusoidal components:



An example signal in the time domain



The same signal in the frequency domain after applying a FFT

The FFT has been historically applied to generally stationary signals but modern day signals, particularly those that are assigned into congested and typically unlicensed bands may be non-stationary in nature as they have to co-exist with other technologies.

An open and broader question underpinning present research is for a wide variety of non-stationary signal types, what analysis benefits are derived from non-FFT based transforms?

Challenge

Over the past 40 years the range and breadth of signal types and wireless systems has grown immensely. Whereas once signals were simple, often using just a single frequency, technology means signals can be complex and non-stationary. This is especially true of contested signals, or those in unlicensed bands.

We want to experiment with the fundamental mathematical form of how wireless systems process and understand modern day, complex, non-stationary signals. The Fast Fourier Transform (FFT) is still a valuable tool, but useful information about the signals could be lost.

For example, we may want information about a signal that is hopping between frequency bands. In this case the frequency and temporal information may be useful. We may want to transform the data so that it can then be processed using, for example, a classifier.

We want to know what other transforms or techniques could be used and their benefits. An initial (not exhaustive) list of possible alternatives are:

- Continuous Wavelet Transform (CWT) & wider wavelet approaches
- Walsh-Hadamard Transform (WHT)
- Hilbert-Huang Transform (HHT)
- Wigner-Ville Transform (WVT)
- Gabor-Wigner Transform (GWT)
- Radon-Wigner Transform (RWT)
- Least squares spectral analysis

Key Questions

- Are there alternative transforms or techniques we have missed?
- What additional benefits do alternatives have over a FFT?
- Are there cases where they would or wouldn't work well? (for example where there is a lot of noise or interference from lots of other signals)
- How can we parameterise these transforms to optimise their performance (for example, selecting the right wavelet for the wavelet transforms)?
- Where there is significant variation in the parameters for different environments, how could this be automated?
- Is there any related work or useful additional references that can be provided?
- Are there any ideas or research proposals that fall out of the problem scope?