DELAYED COMPARISON ERROR MINIMIZATION FOR FREQUENCY DOMAIN STATE ESTIMATION IN STRUCTURES SUBJECTED TO HIGH-RATE BOUNDARY CHANGE

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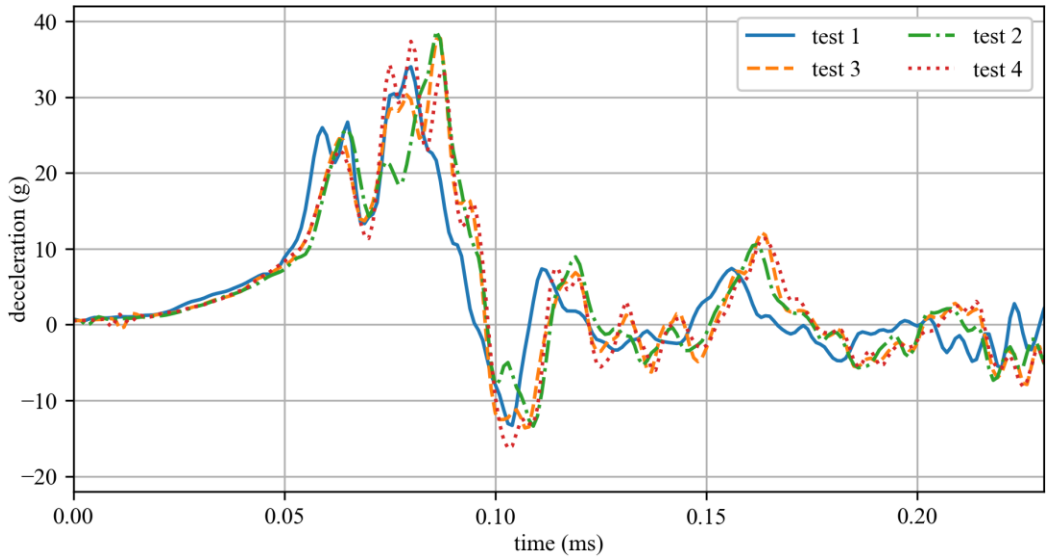
BACKGROUND: APPLICATIONS AND CHALLENGES

- Many structures experience dynamic conditions with moving boundaries.
- Frequency measurement can be used to infer the state/condition of a structural system.
- Measuring frequency in real-time of a structure experiencing high-rate boundary changes presents unique challenges.

Team Eglin Public Affairs

BACKGROUND: DROP TOWER TESTING

- Consecutive tests may generate varying loads.
- Structure response inconsistent if damage accumulates.



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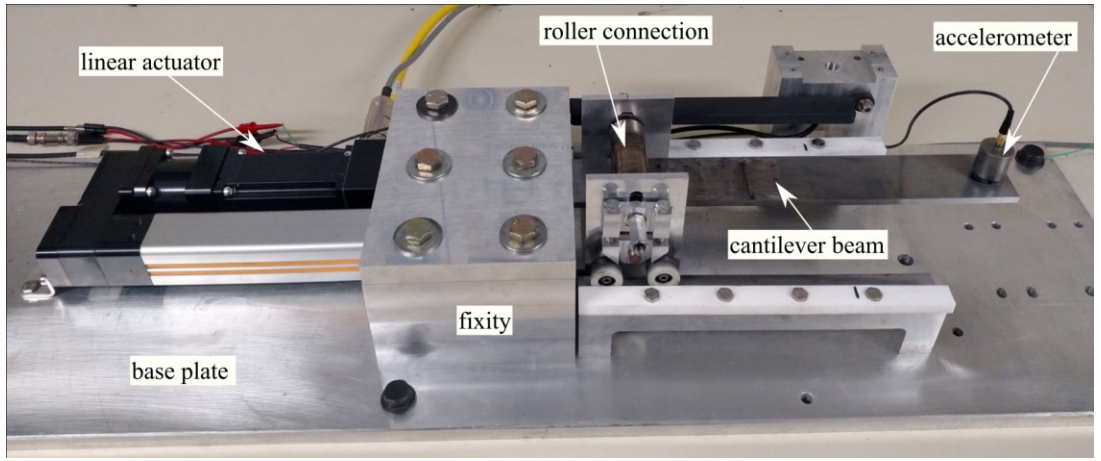
BACKGROUND: DROPBEAR

- The Dynamic Reproduction of Projectiles in Ballistic Environments for Advanced Research (DROPBEAR).

- Goal: estimate roller location in real-time using accelerometer output.



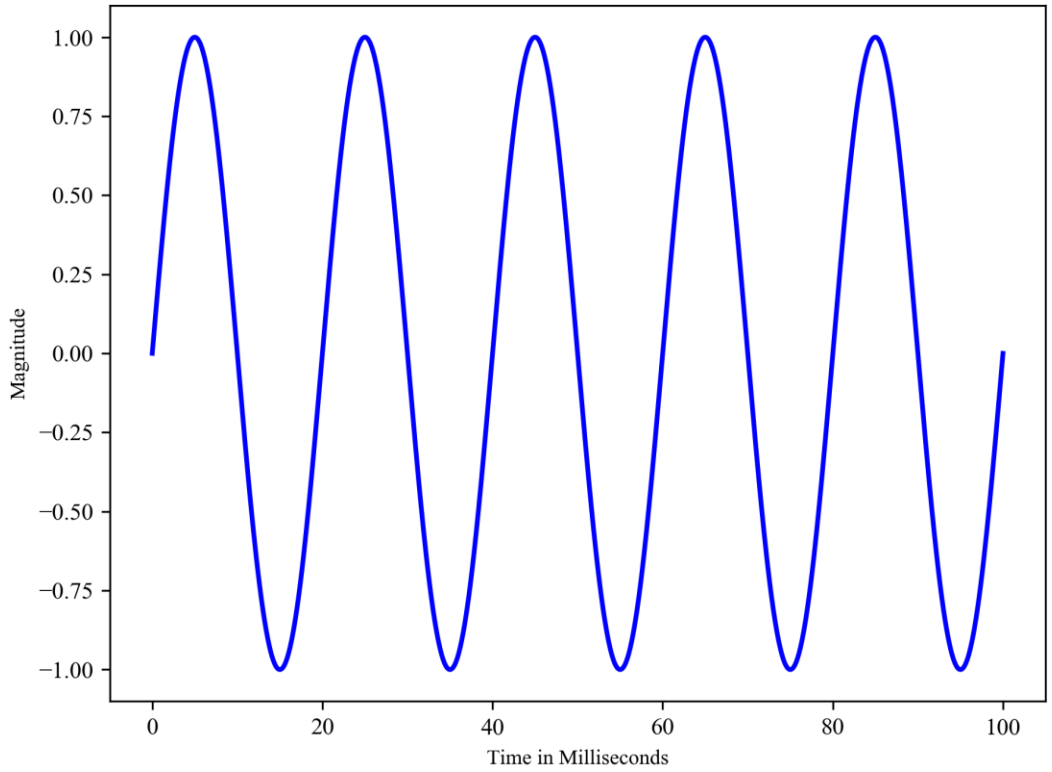
INVESTIGATION INTO SOLUTIONS

- Investigation into methods of determining frequency:

  -FFT Based Method
  -Delayed Comparison Error Minimization
  -MLP Regression Neural Network
  -Hybrid Method

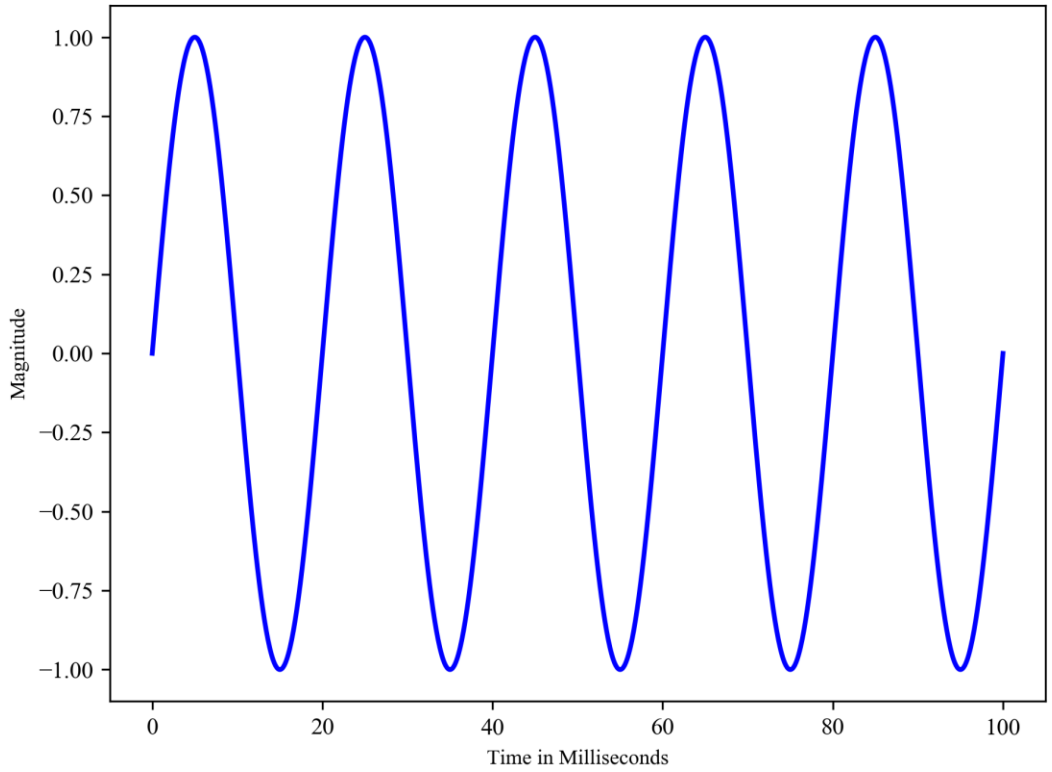
DCEM: DELAYED COMPARISON ERROR MINIMIZATION

- DCEM, Delayed Comparison Error Minimization, compares a section of a periodic waveform to sections with known time differences. By determining what time difference results in the nearest match, the waveform's frequency can be determined.



DCEM: WAVELENGTH/PERIOD

- Wavelength, or period, is the space or time distance between repetitions of the same wave shape. Ex, a 50Hz wave has a period of 20ms.



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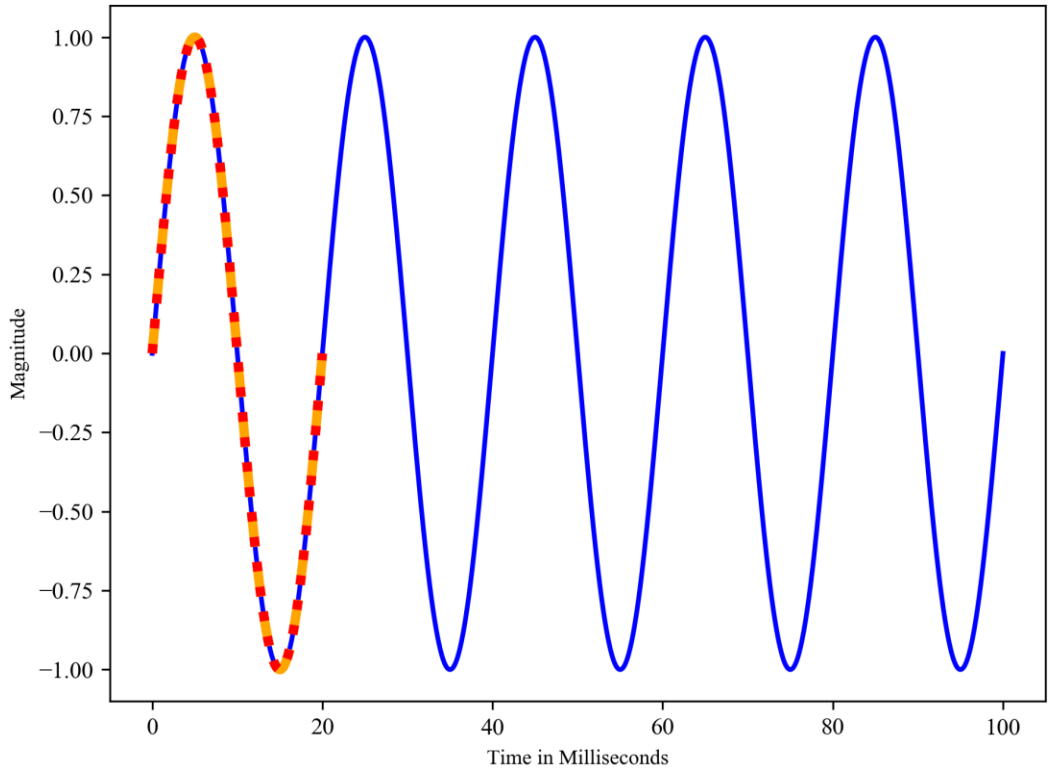

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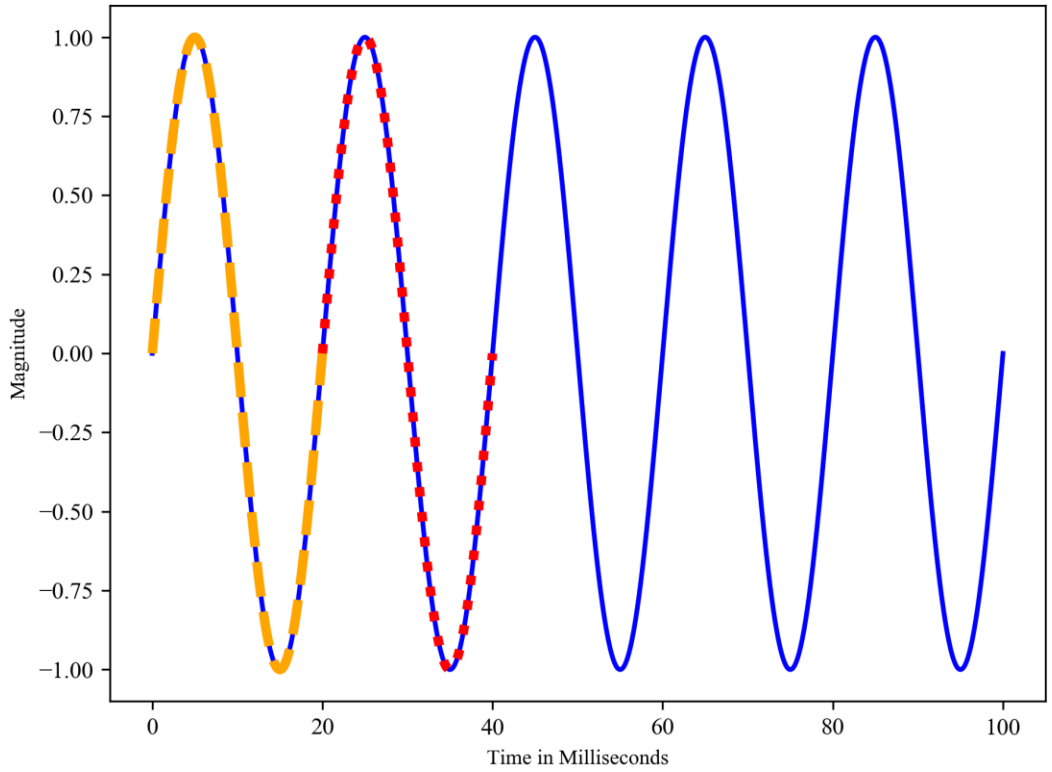

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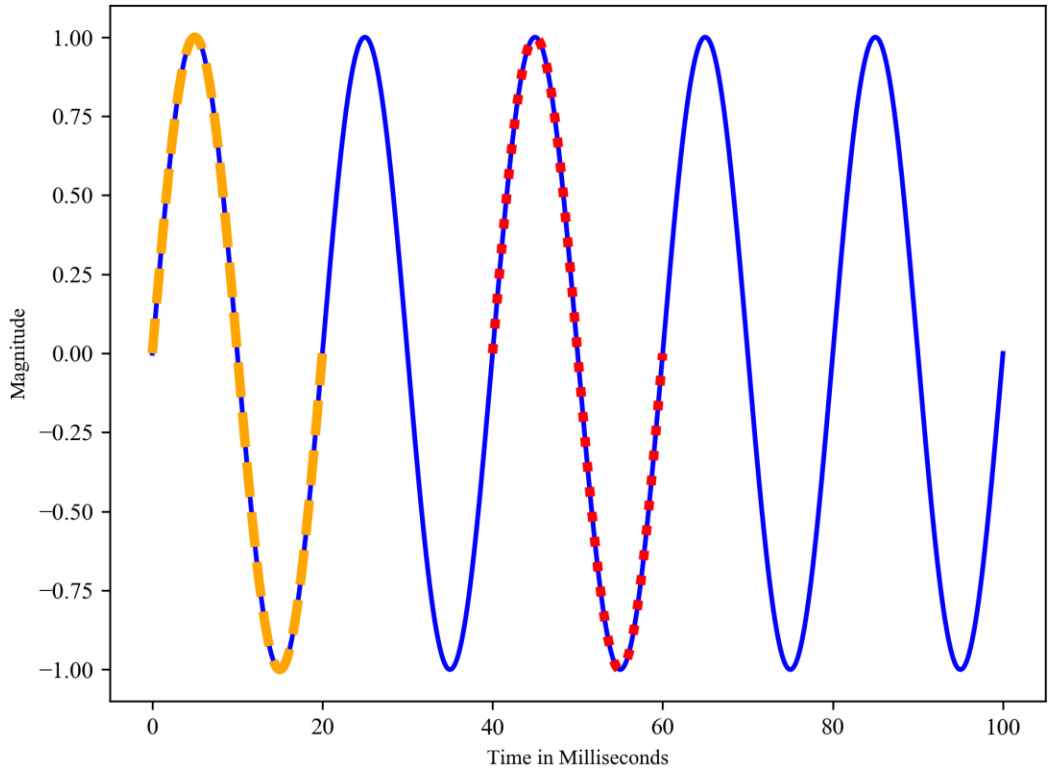
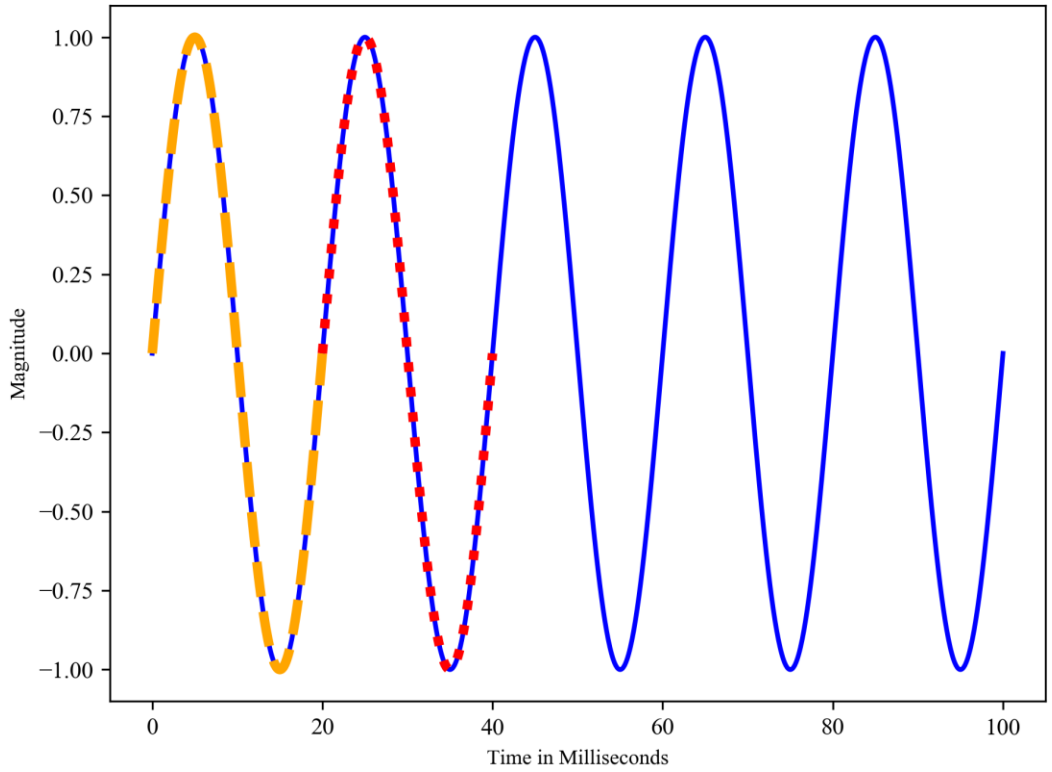


DCEM: MATCH

- Comparing sections with a known time difference between them allows determination of the period.
- When the time difference is equal to a multiple of the period (20ms @ 50Hz), the difference between two samples will be zero.



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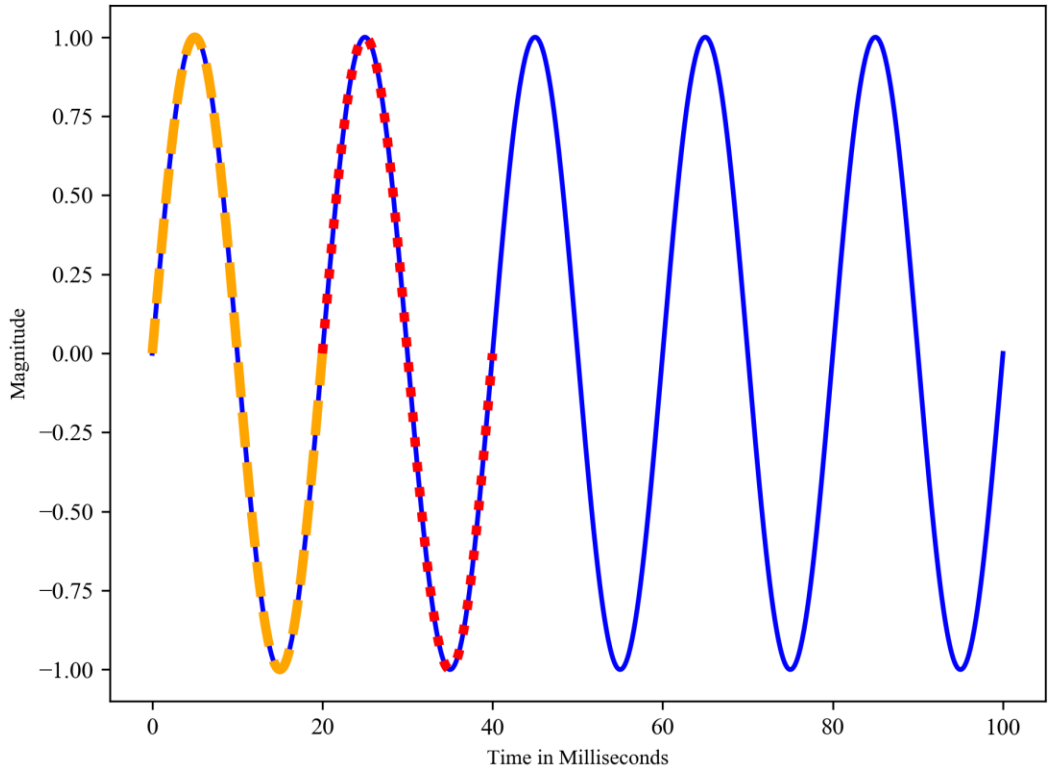
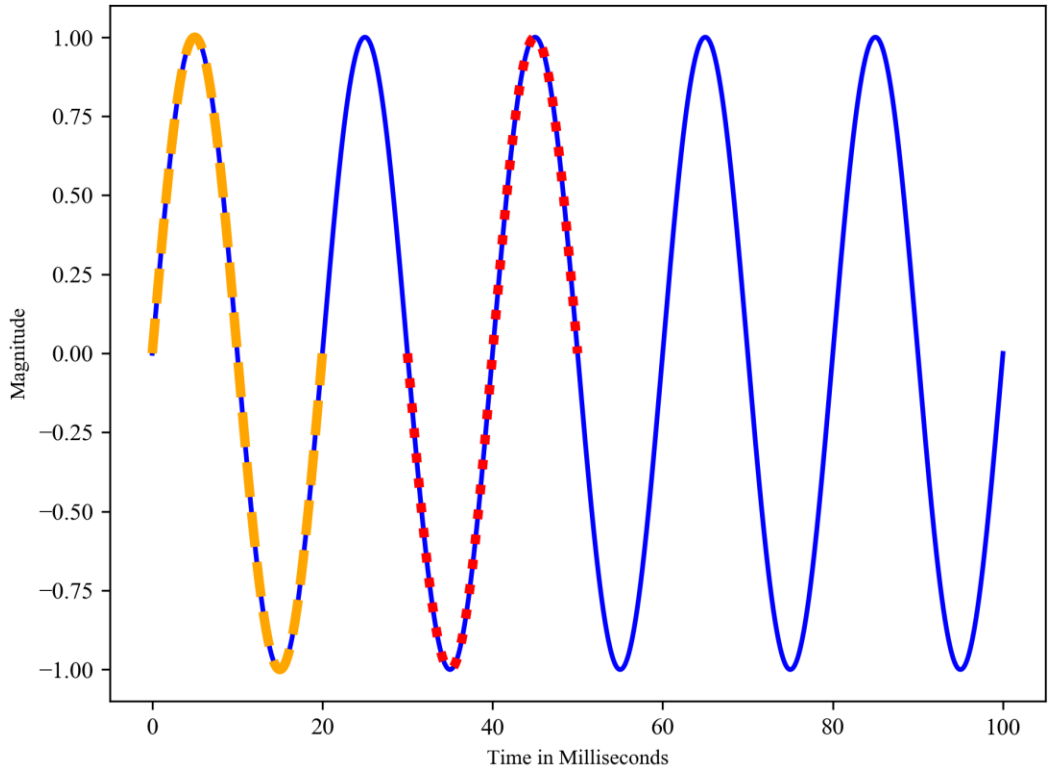


DCEM: MISMATCH

- When the time difference is not equal to a multiple of the period, there will be some difference.
- Comparing samples with 30ms of offset, on a wave with a 20ms period, shows a large difference.



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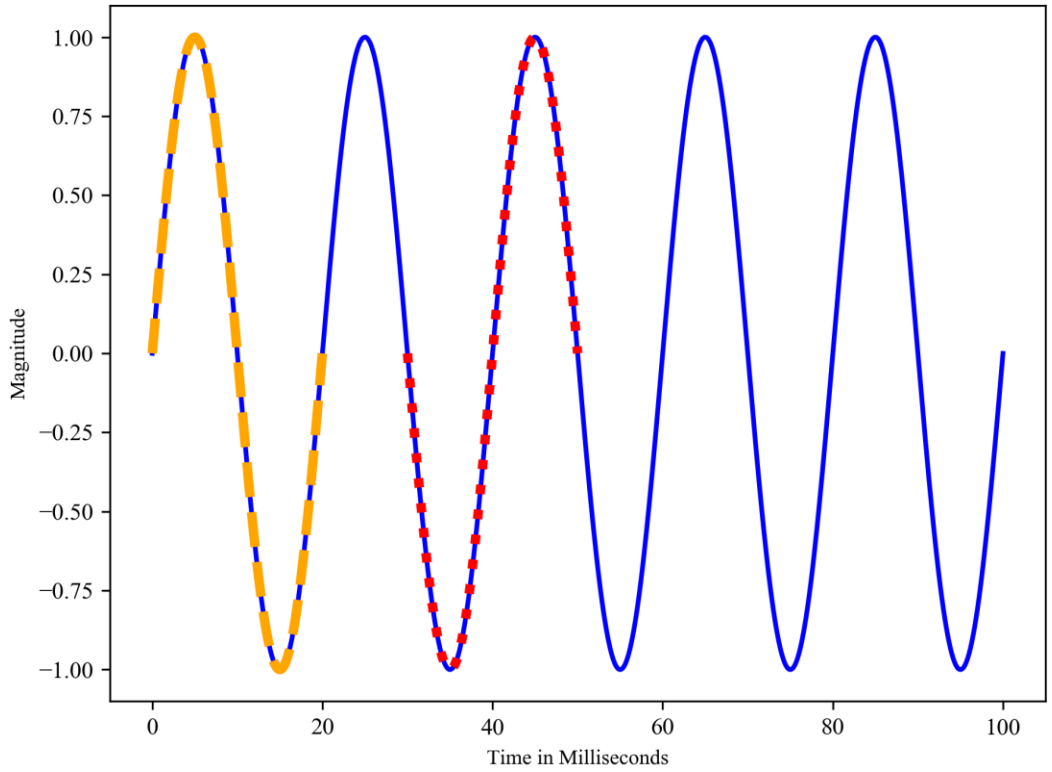
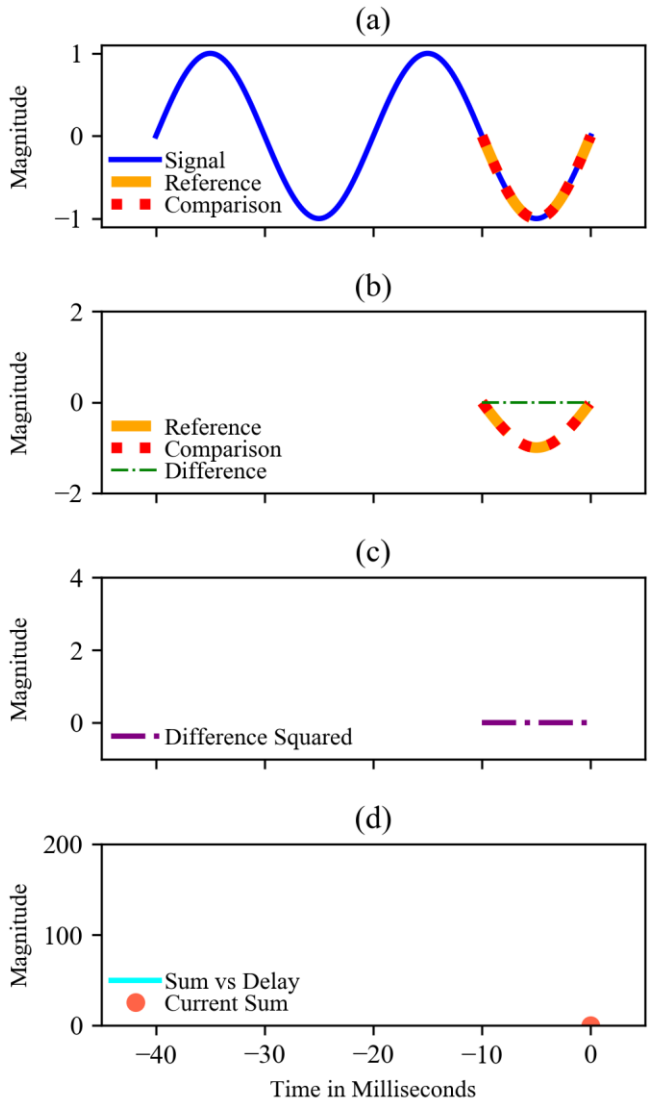


DCEM: USE

- This concept can be used to find the period of a given waveform.
- Comparing samples of different offsets/delays and seeing which results in maximum similarity, or minimum difference, gives the period of a wave.



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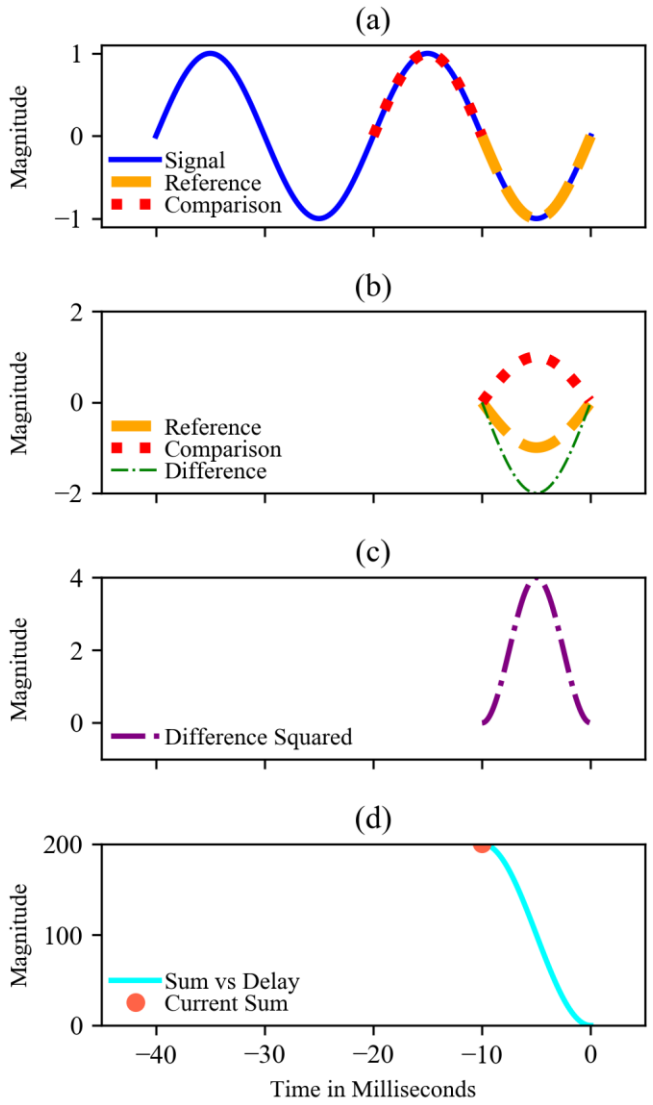

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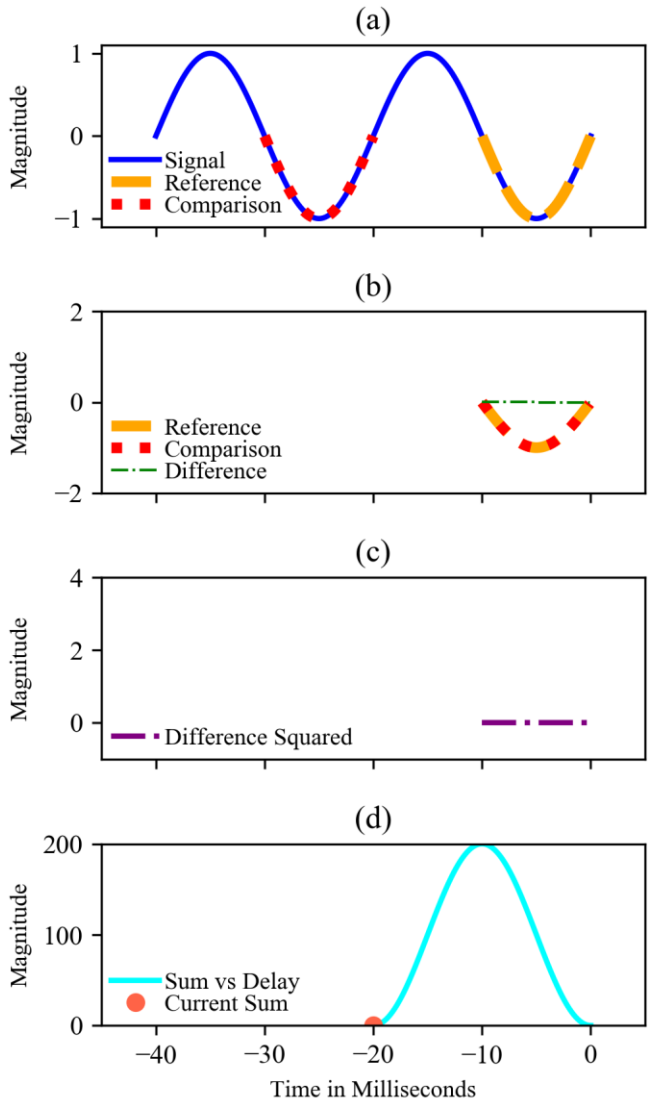

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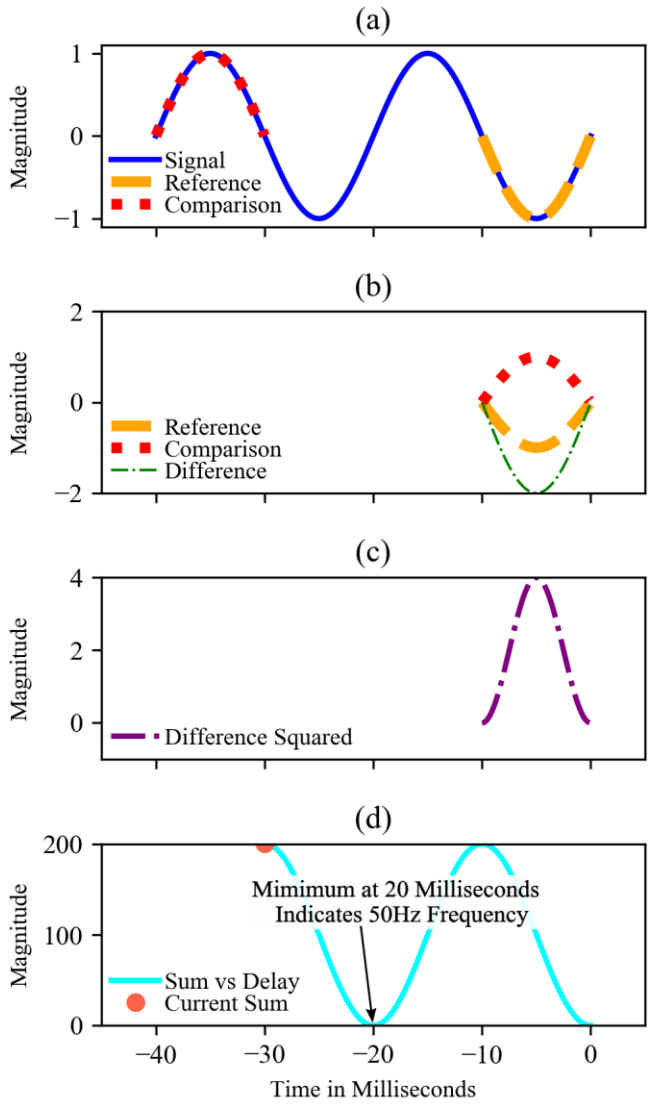
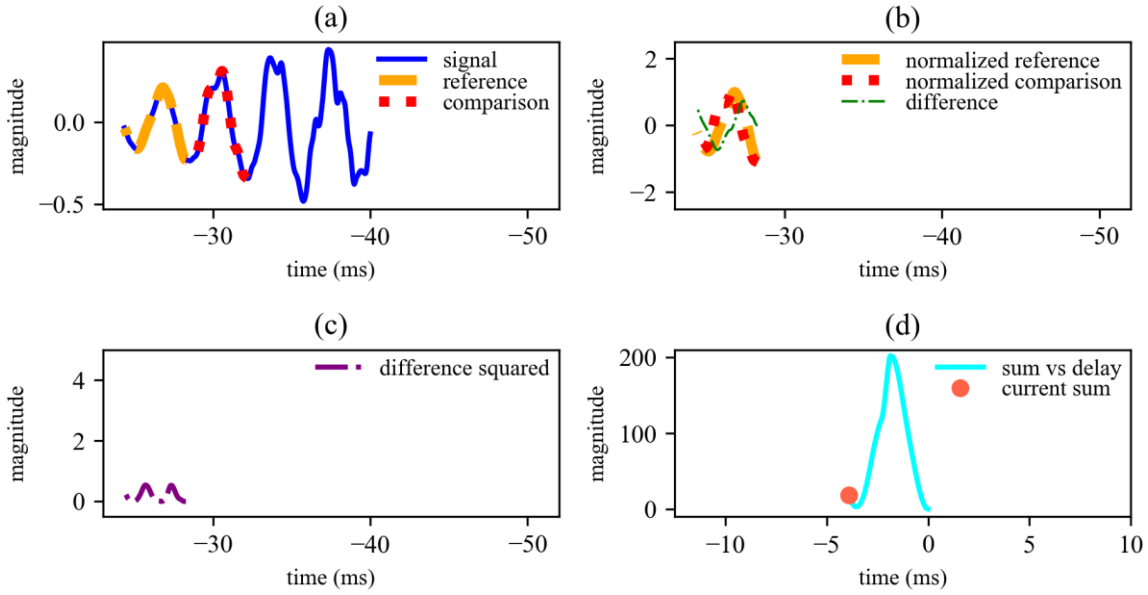


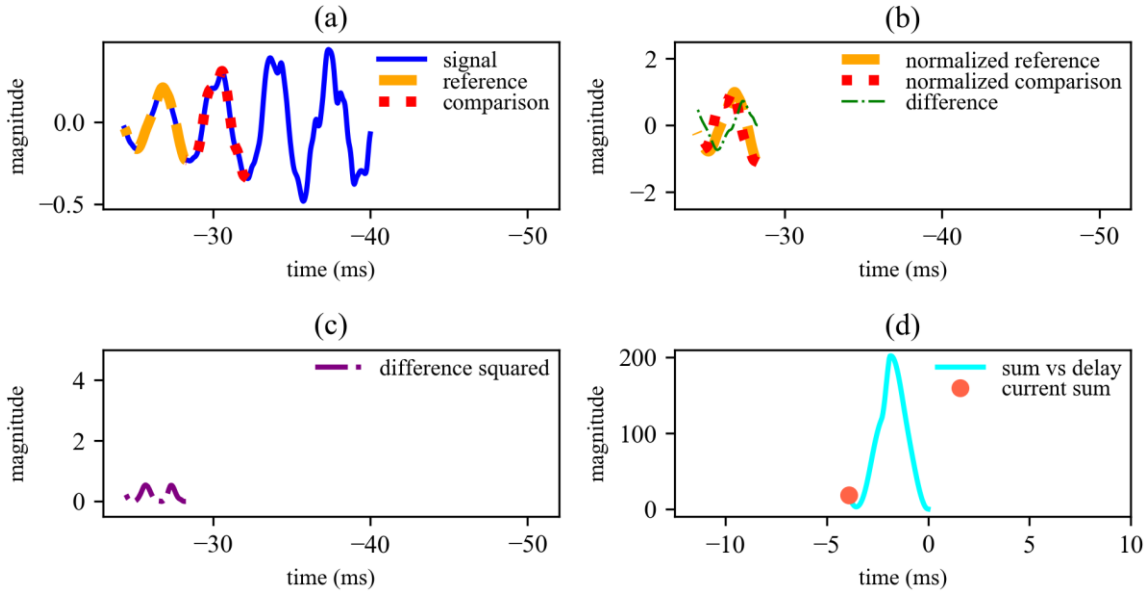
MLP REGRESSION

- Built using TensorFlow, 2 64 node layers plus output layer.
- Pre-trained for 1,000 epochs.
- Training + verification data set consists of 22,140 sinusoids, each 100 values long and of unique frequency and phase.



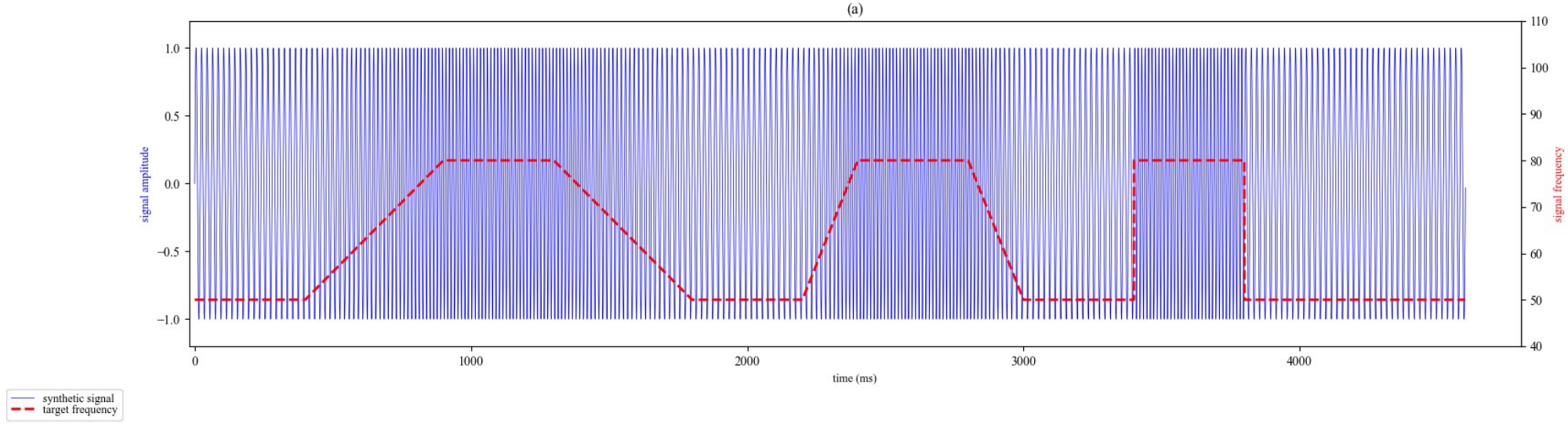
MLP DCEM HYBRID

- Modified DCEM “sum vs delay” output fed into MLP.
- Training + verification data set consists of 200 sinusoids, each 300 values long and of unique frequency but each the same phase.
- Intent is to eliminate sensitivity to, or need to train for, phase.



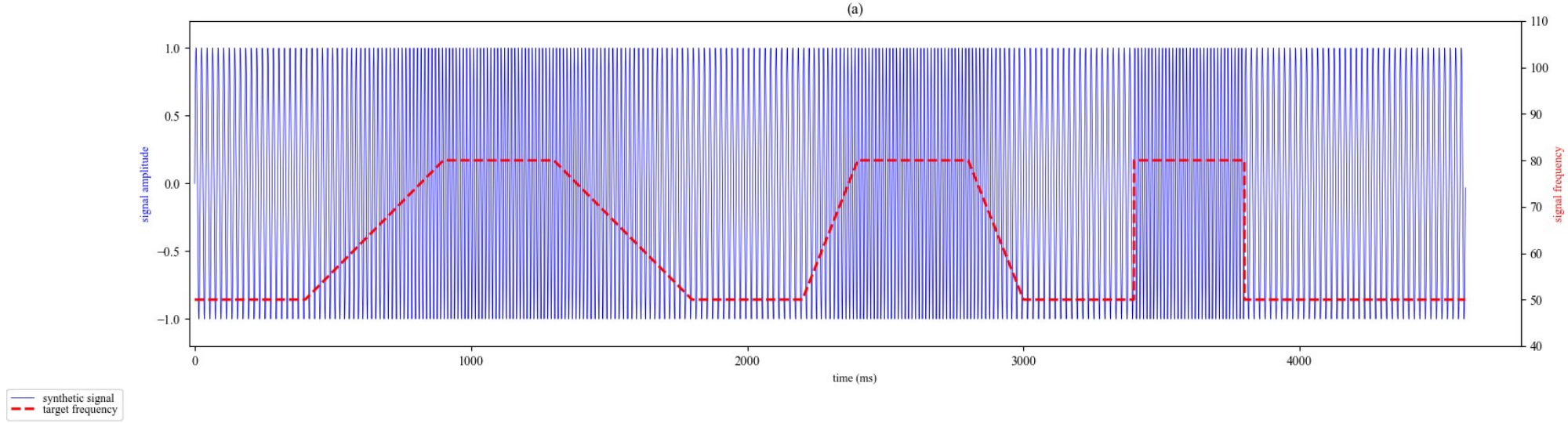
NUMERICAL ANALYSIS: CONSTANT AMPLITUDE

- Performance at this stage was analyzed by running each method on a data set containing known frequencies.



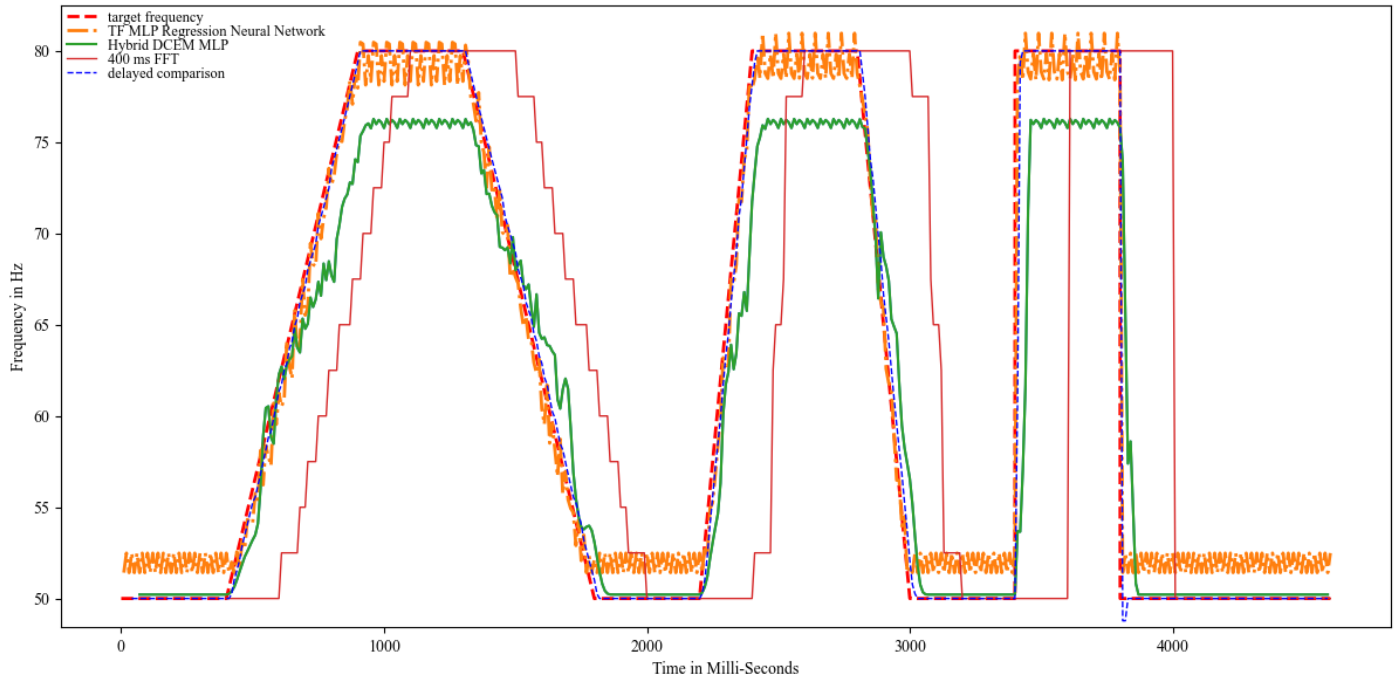
NUMERICAL ANALYSIS: CONSTANT AMPLITUDE

- Data set starts at a constant 50hz, followed by a slow frequency sweep up, holding at the higher frequency, then a slow sweep down, followed by a similar pattern with a faster pair of sweeps and then frequency steps.



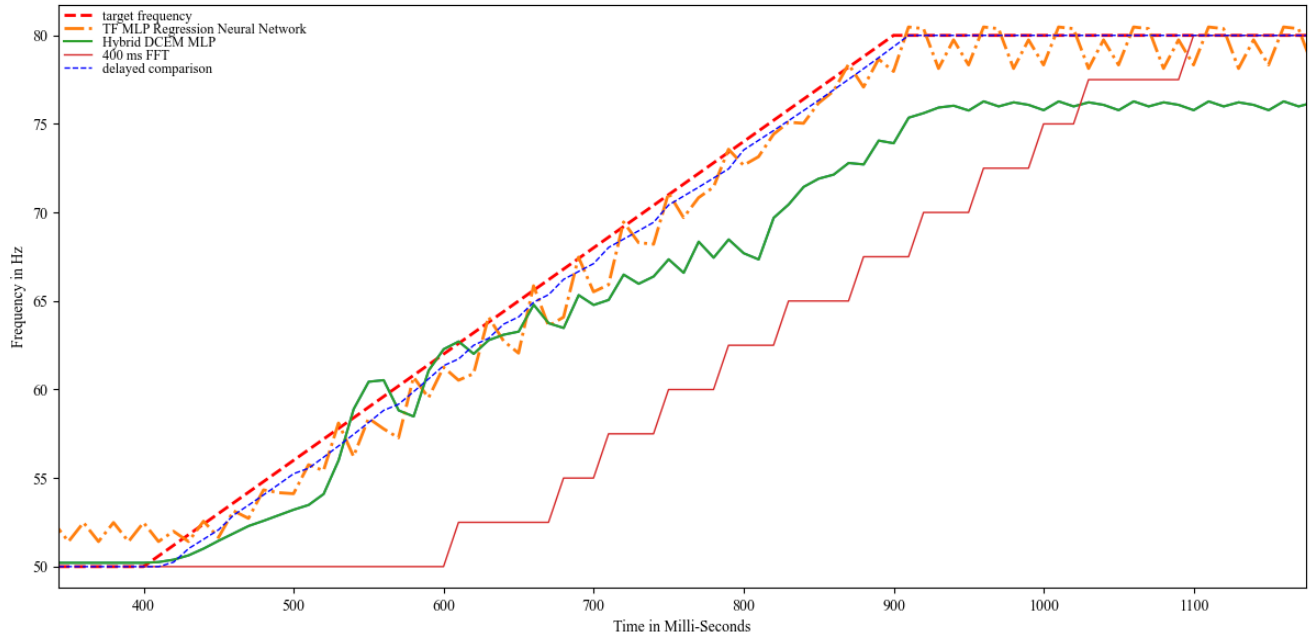
NUMERICAL ANALYSIS: CONSTANT AMPLITUDE

- When each frequency identification method is run on this signal, they give the outputs shown:



NUMERICAL ANALYSIS: CONSTANT AMPLITUDE

- A closer inspection of the results given at the beginning of the first sweep helps to show the difference between the FFT, direct neural network, and hybrid method output.



THANKS!