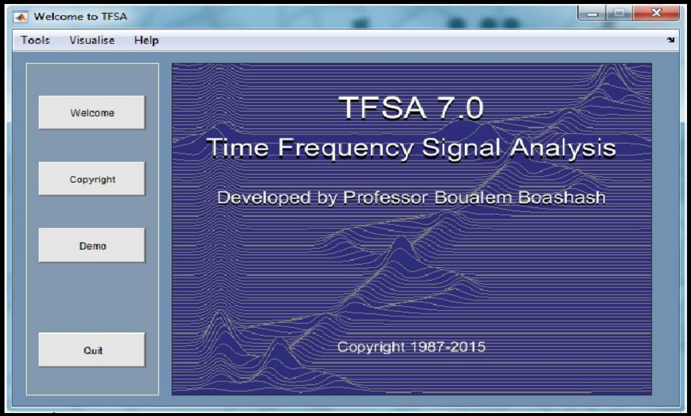
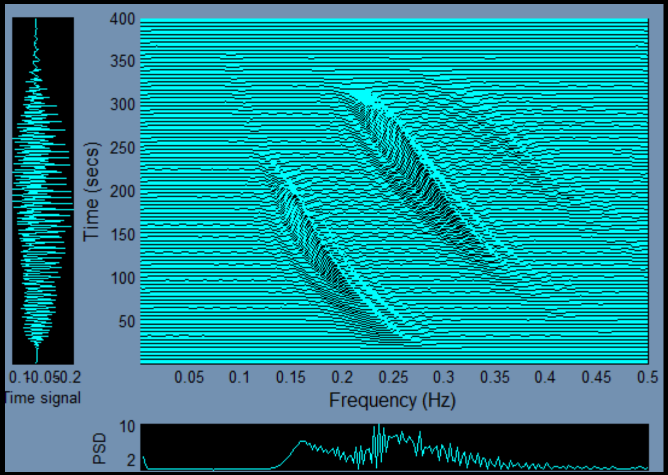
PART B:
TFSA 7.0 Tutorial





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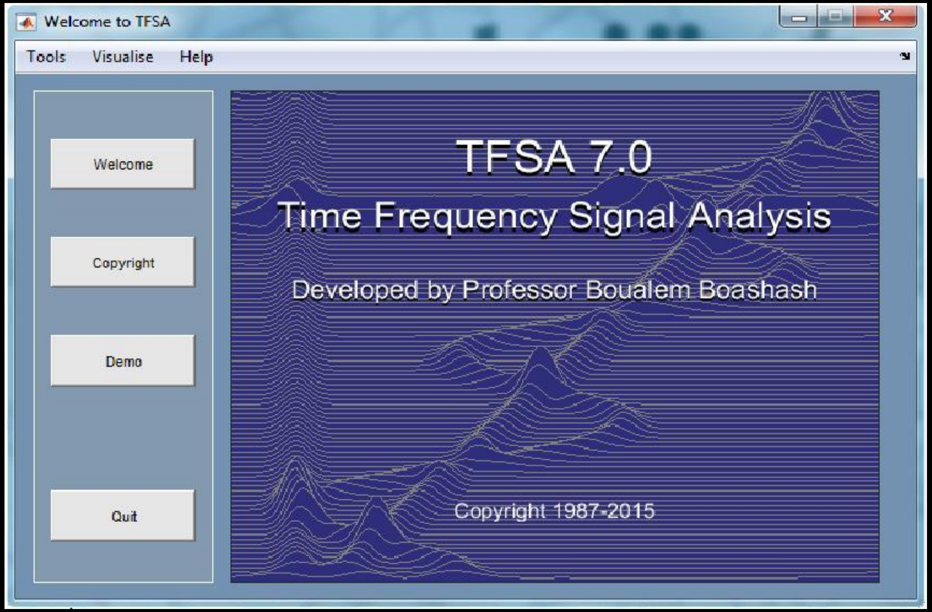
[c] *formerly* Director, SPRC, Queensland University of Technology, Brisbane, Australia

TFSA Toolbox

- Time-Frequency Signal Analysis Matlab® Toolbox
- Developed by Prof. Boualem Boashash
- Graphical User Interface
- MEX formatting
- UNIX and WINDOWS
- 20 years of development
- Additional information can be found at:



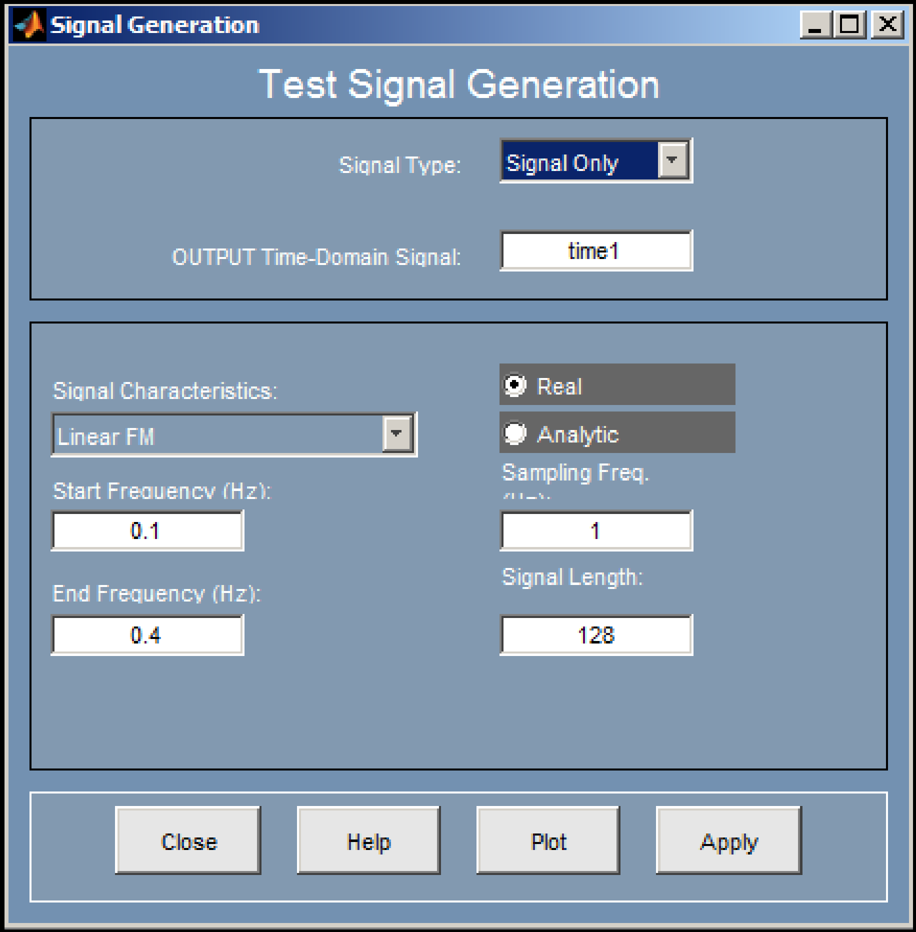
http://www.time-frequency.net/downloads.html

Content

- The toolbox addresses the issues of
  - Nonstationary signal generation
  - Analytic signal generation
  - Quadratic time-frequency distributions
  - Instantaneous frequency estimation
  - Time-frequency signal synthesis

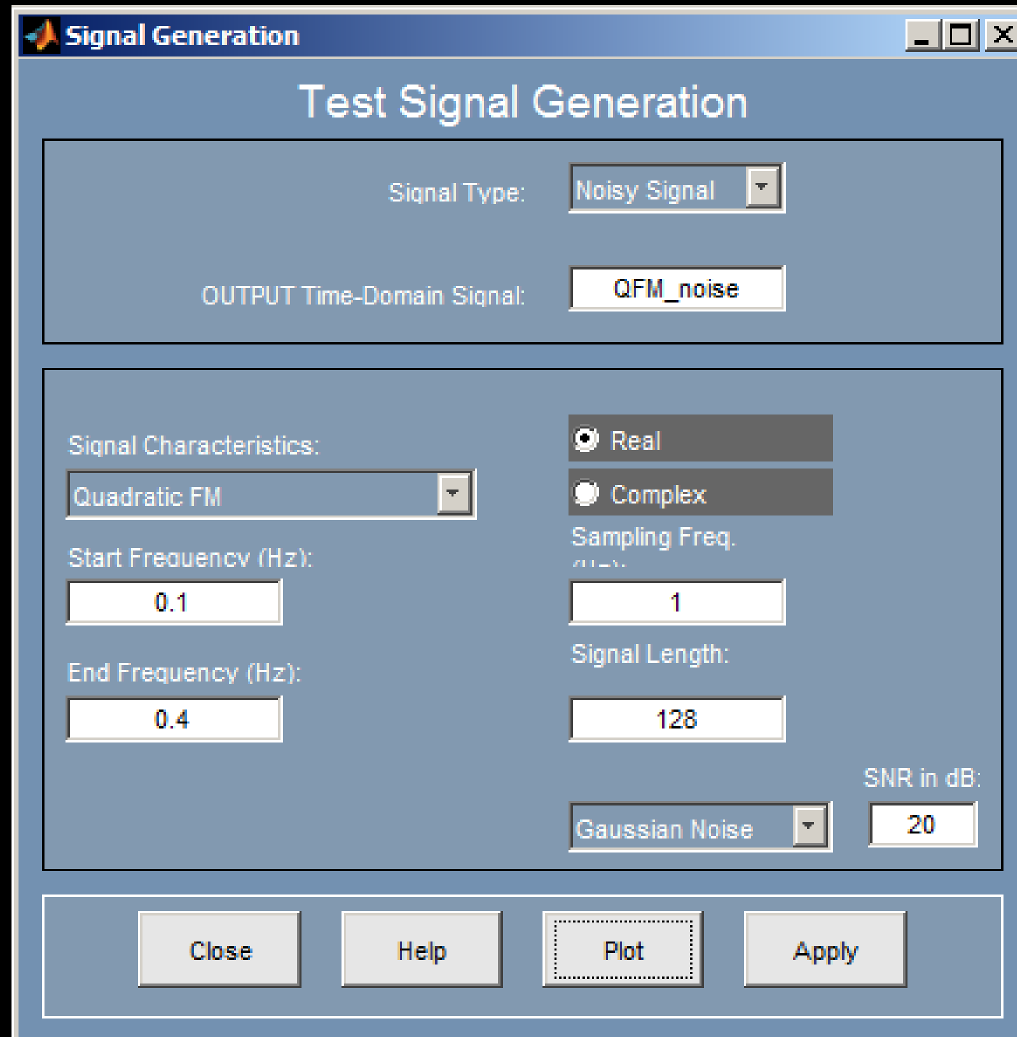
Signal Generation

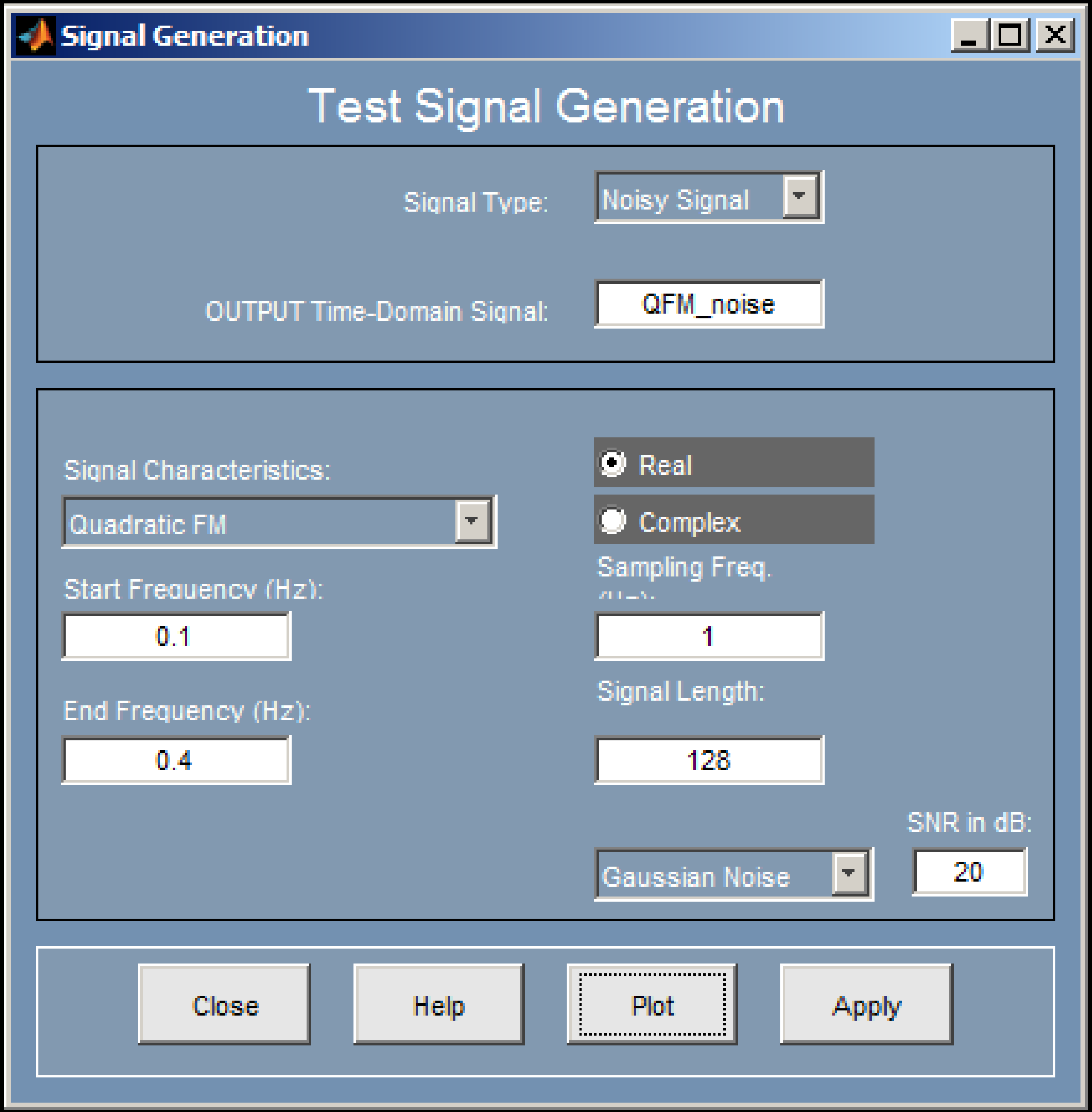
- Types of signal generated
  - Linear FM
  - Quadratic FM
  - Cubic FM
  - Hyperbolic FM
  - Sinusoidal FM
  - Stepped FM
  - Noise
    - Gaussian
    - Uniform
  - Signal + Noise
    - SNR
  - Real or Complex



Example: - Quadratic FM + noise

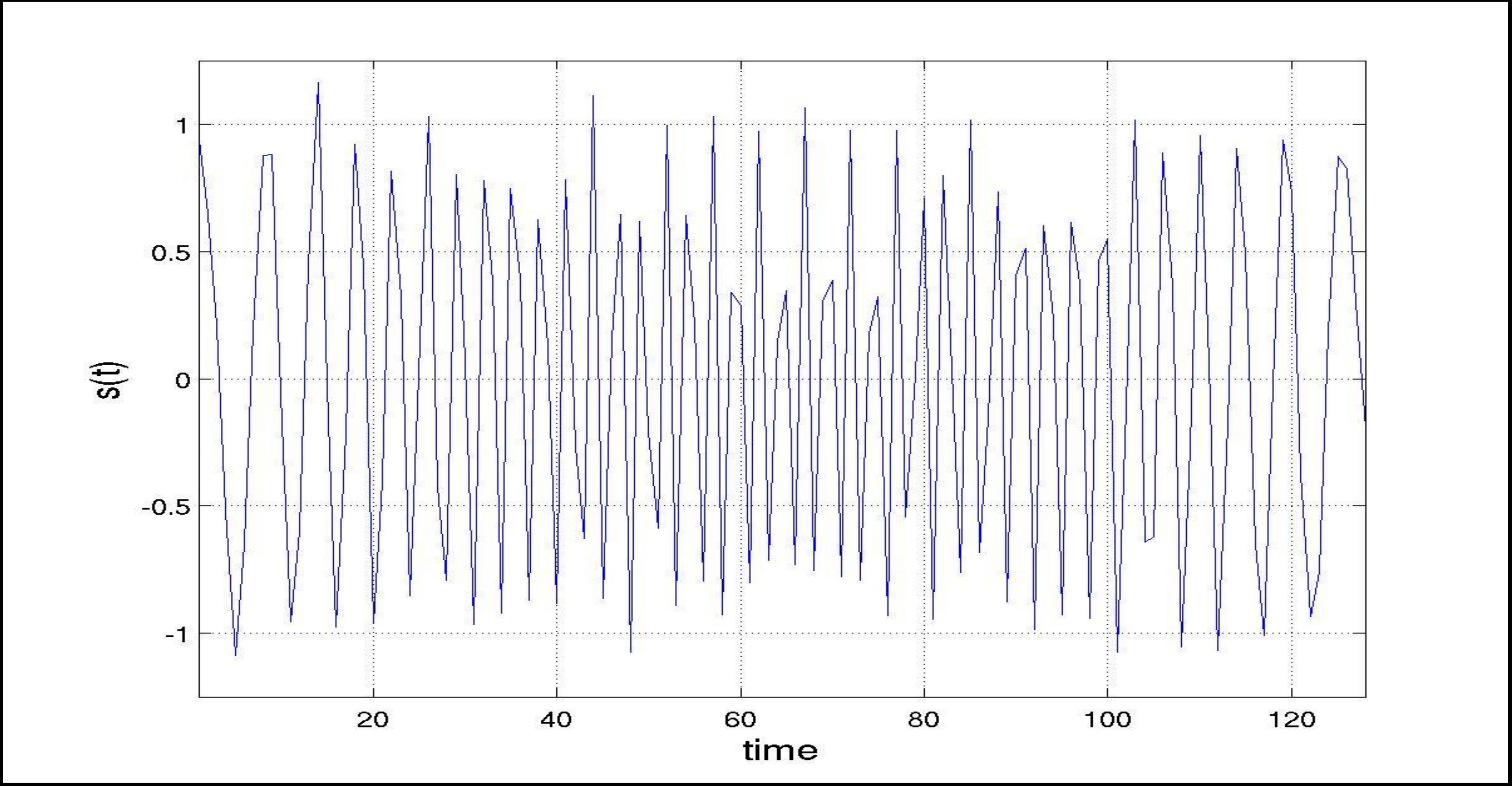
Generate a real quadratic FM signal (length = 128 samples) that ranges from 0.1 to 0.4 Hz (normalised) with AWGN (SNR = 20dB).




Signal Generation
Test Signal Generation
Signal Type:
Noisy Signal
OUTPUT Time-Domain Signal:
QFM_noise
Signal Characteristics:
Quadratic FM
Real
Complex
Sampling Freq.
Start Frequency (Hz):
0.1
1
End Frequency (Hz):
0.4
Signal Length:
128
SNR in dB:
Gaussian Noise
20
Close
Help
Plot
Apply

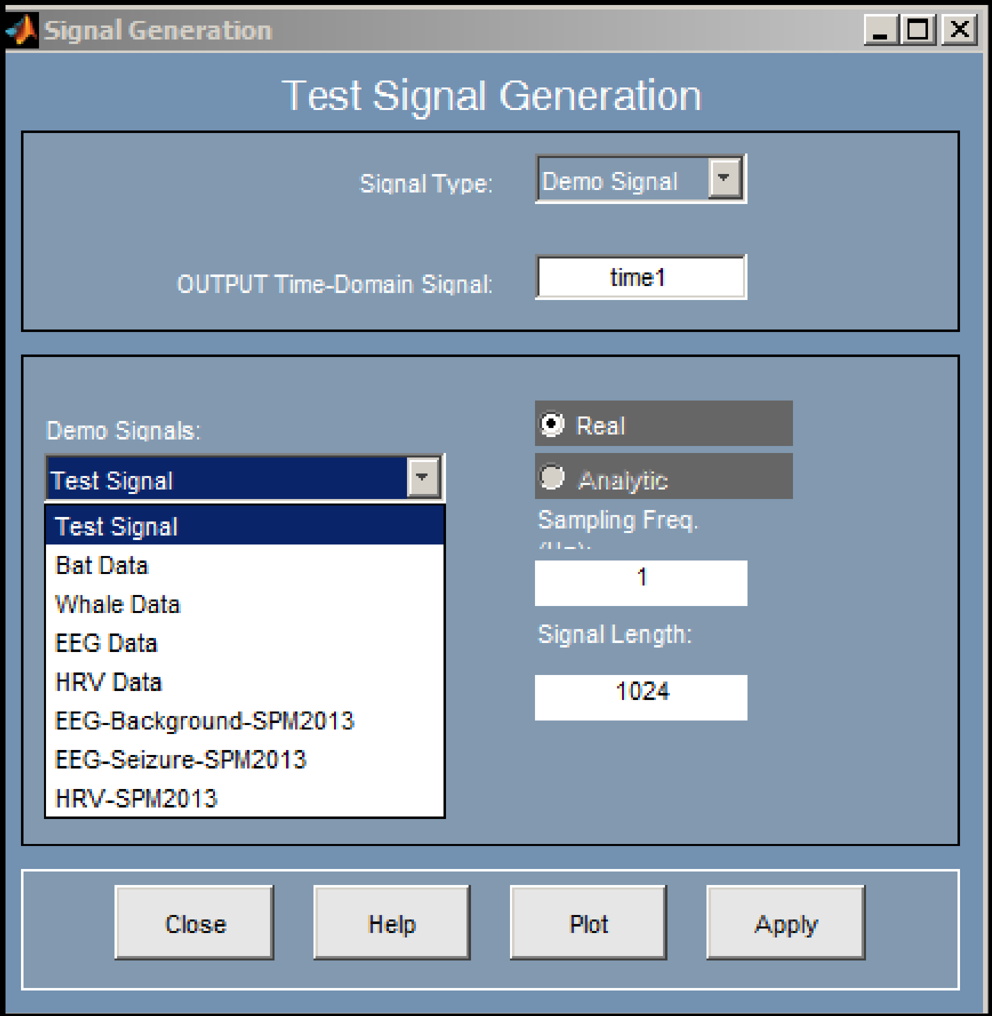
Generated Signal

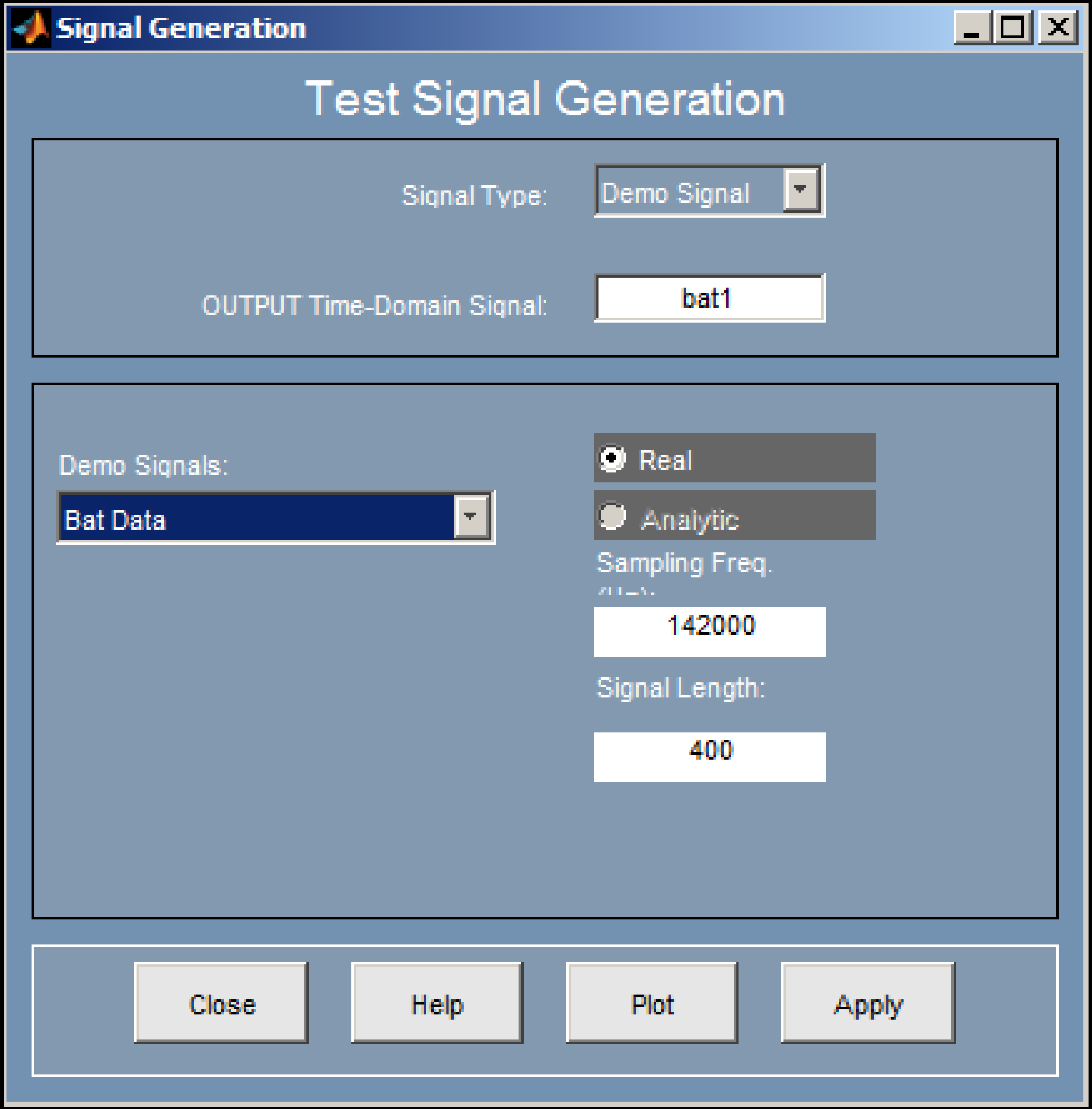
\>> plot(QFM_noise)



Demo Signals

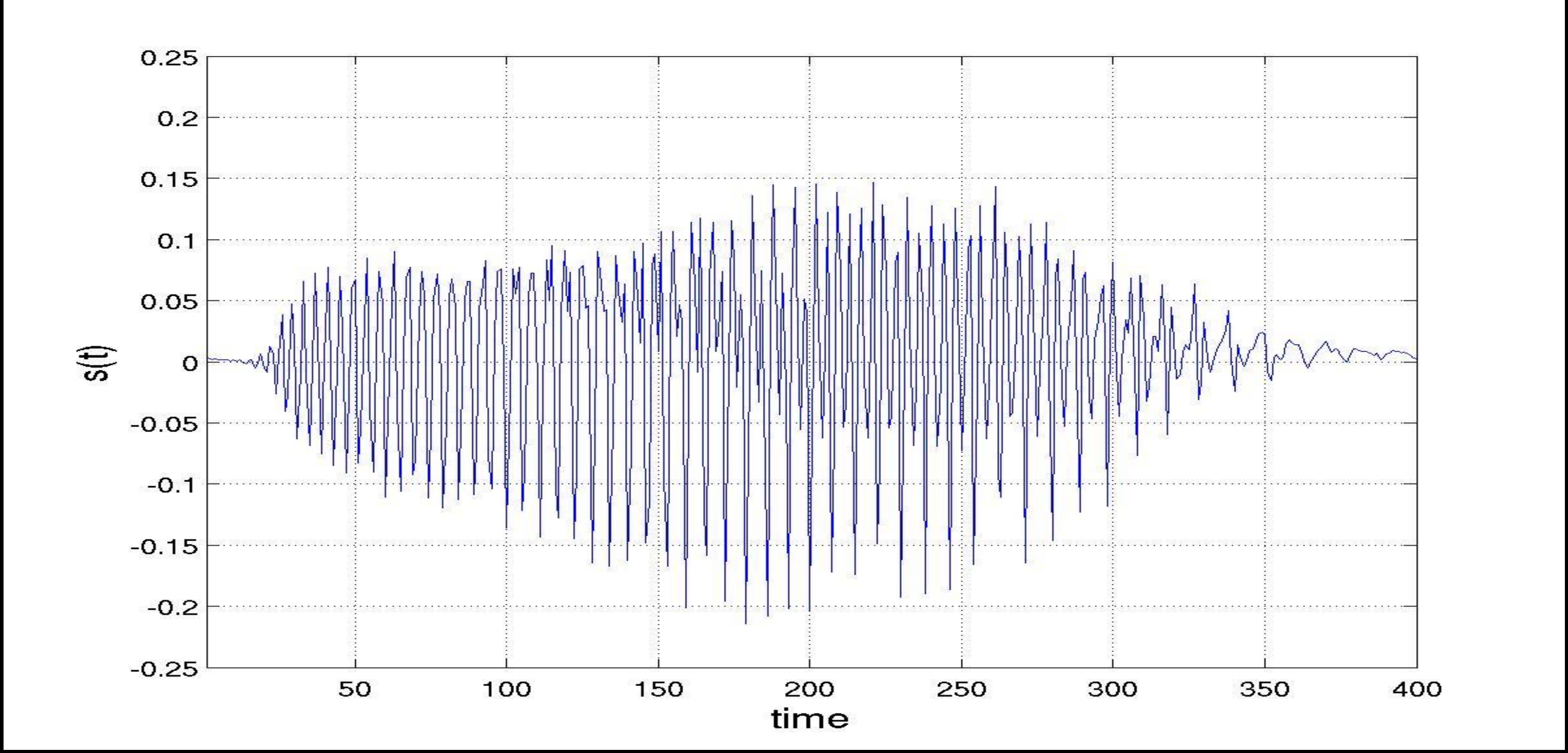
- Database of real world nonstationary example signals
  - Whale Song
  - Bat
  - Newborn EEG
  - HRV
  - Arbitrary test signal




Signal Generation
Test Signal Generation
Signal Type:
Demo Signal
OUTPUT Time-Domain Signal:
bat1
Demo Signals:
Bat Data
Real
Analytic
Sampling Freq.
142000
Signal Length:
400
Close
Help
Plot
Apply

Example

- Bat echolocation >> plot(bat1)



Analytic Signal Generation

- The analytic signal is an important fundamental concept in time-frequency signal analysis (chapter 1)

$$z(t) = s(t) + j\left[s(t) \underset{t}{*} \frac{1}{\pi t} \right]$$

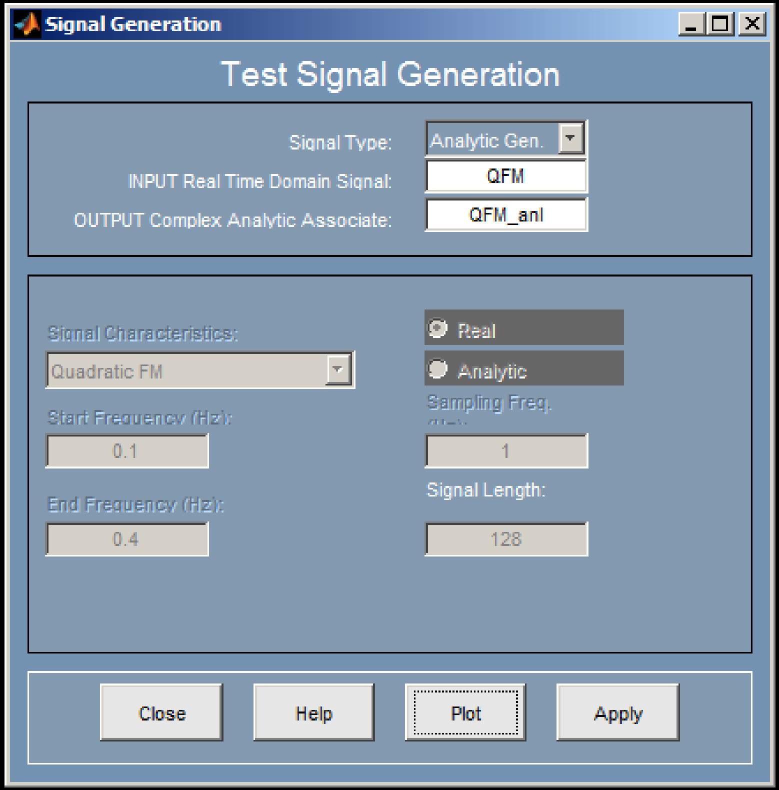
- In polar form

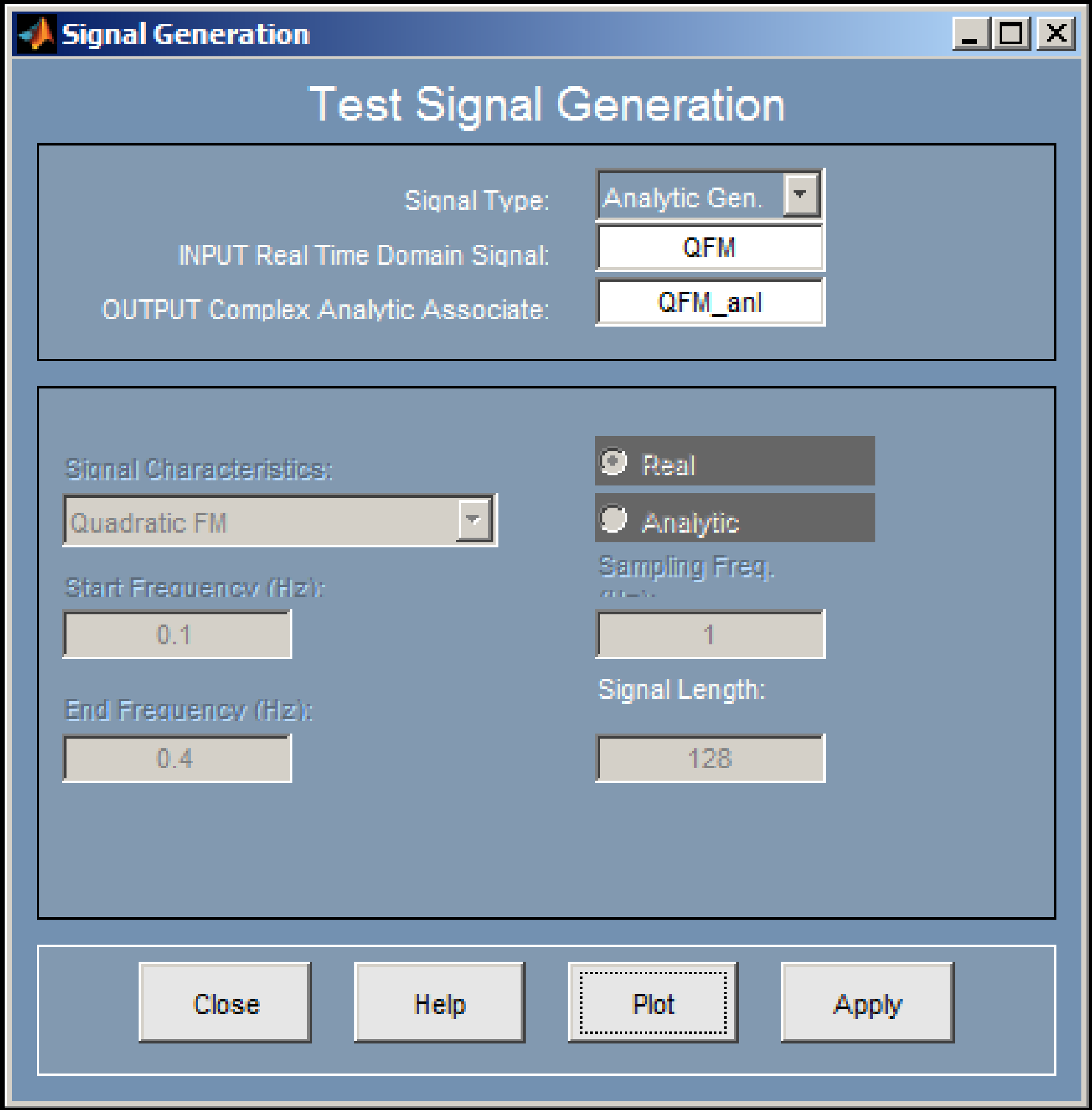
$$z(t) = a(t) e^{j\phi(t)}$$

- TFSA generates the analytic signal using a frequency domain method.

Analytic Signal Example

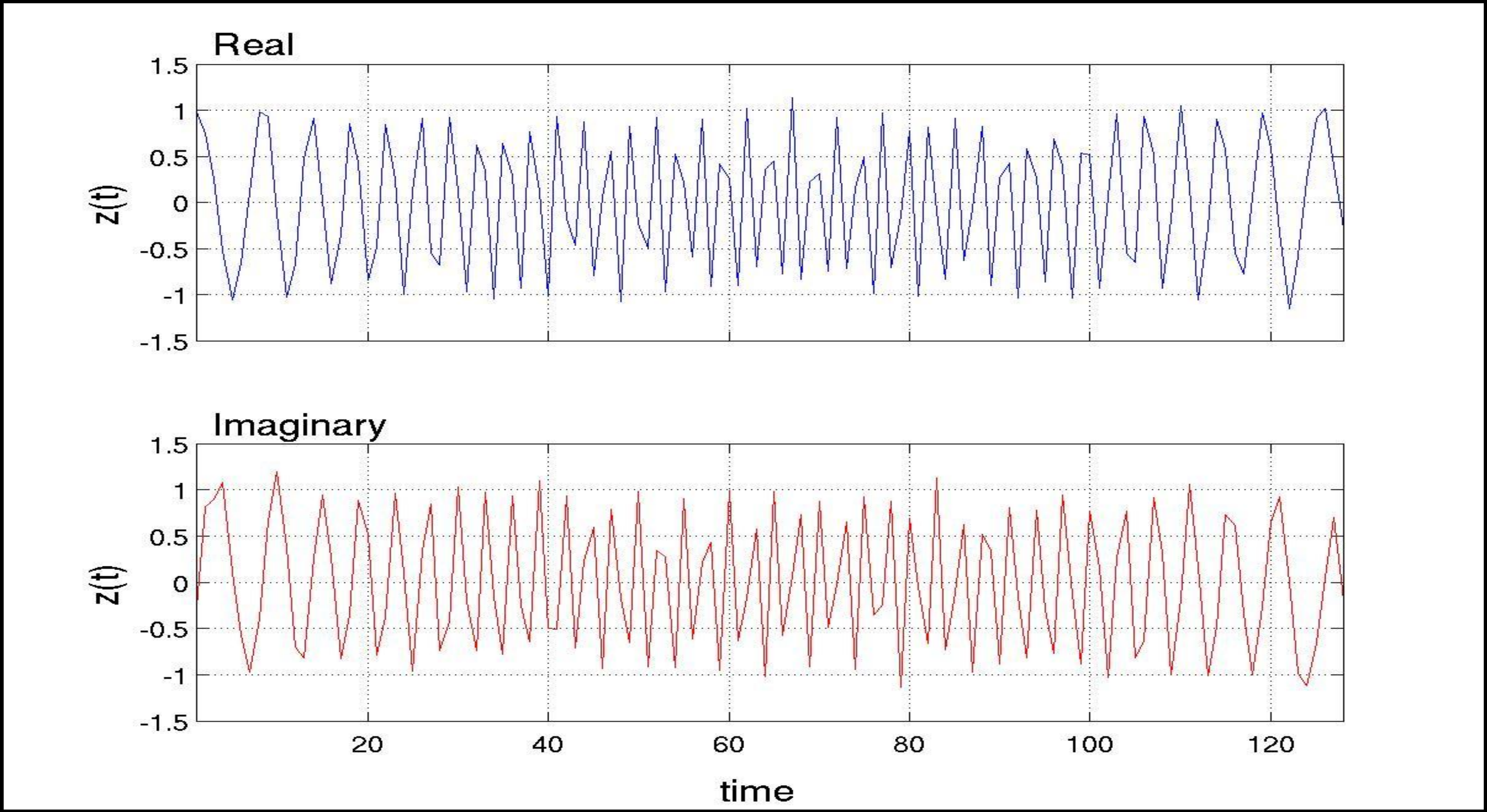
- Generate the analytic signal of the quadratic FM signal




Signal Generation
Test Signal Generation
Signal Type:
Analytic Gen.
INPUT Real Time Domain Signal:
QFM
OUTPUT Complex Analytic Associate:
QFM_anl
Signal Characteristics:
Quadratic FM
Start Frequency (Hz):
0.1
End Frequency (Hz):
0.4
Real
Analytic
Sampling Freq.
1
Signal Length:
128
Close
Help
Plot
Apply

Analytic Signal Example

>> plot(real(QFM_anl)); hold; plot(imag(QFM_anl,'r'))



IF estimation

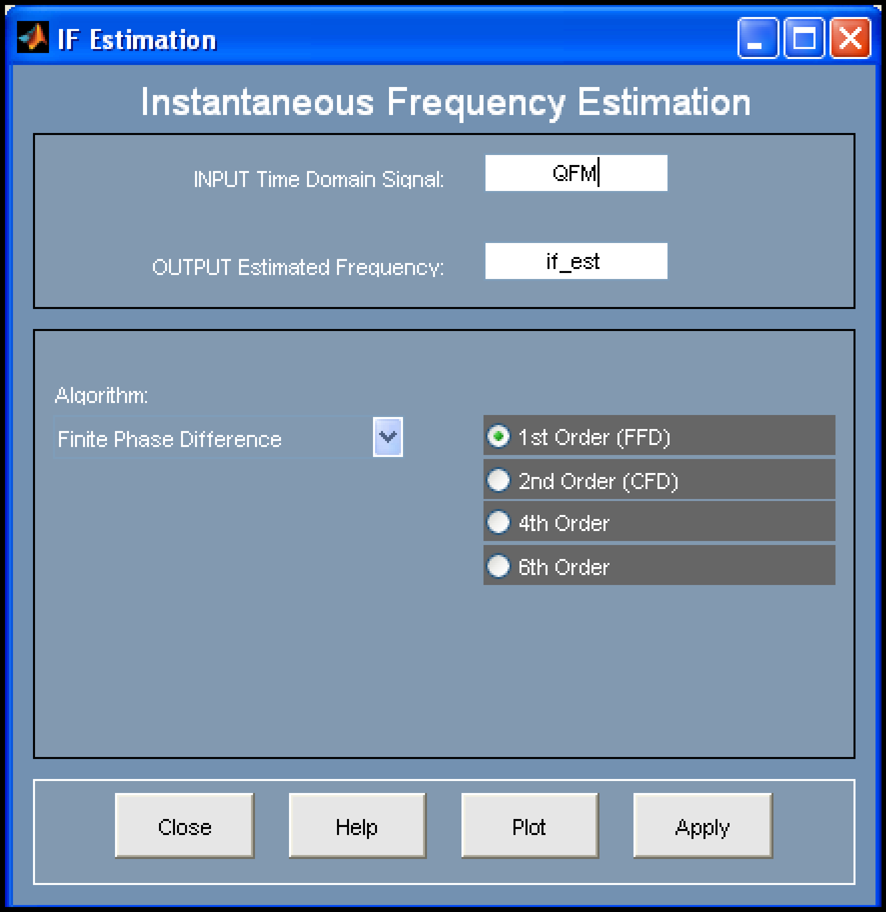
- Analytic signal can be used to directly estimate the IF of a signal (chapter 1)

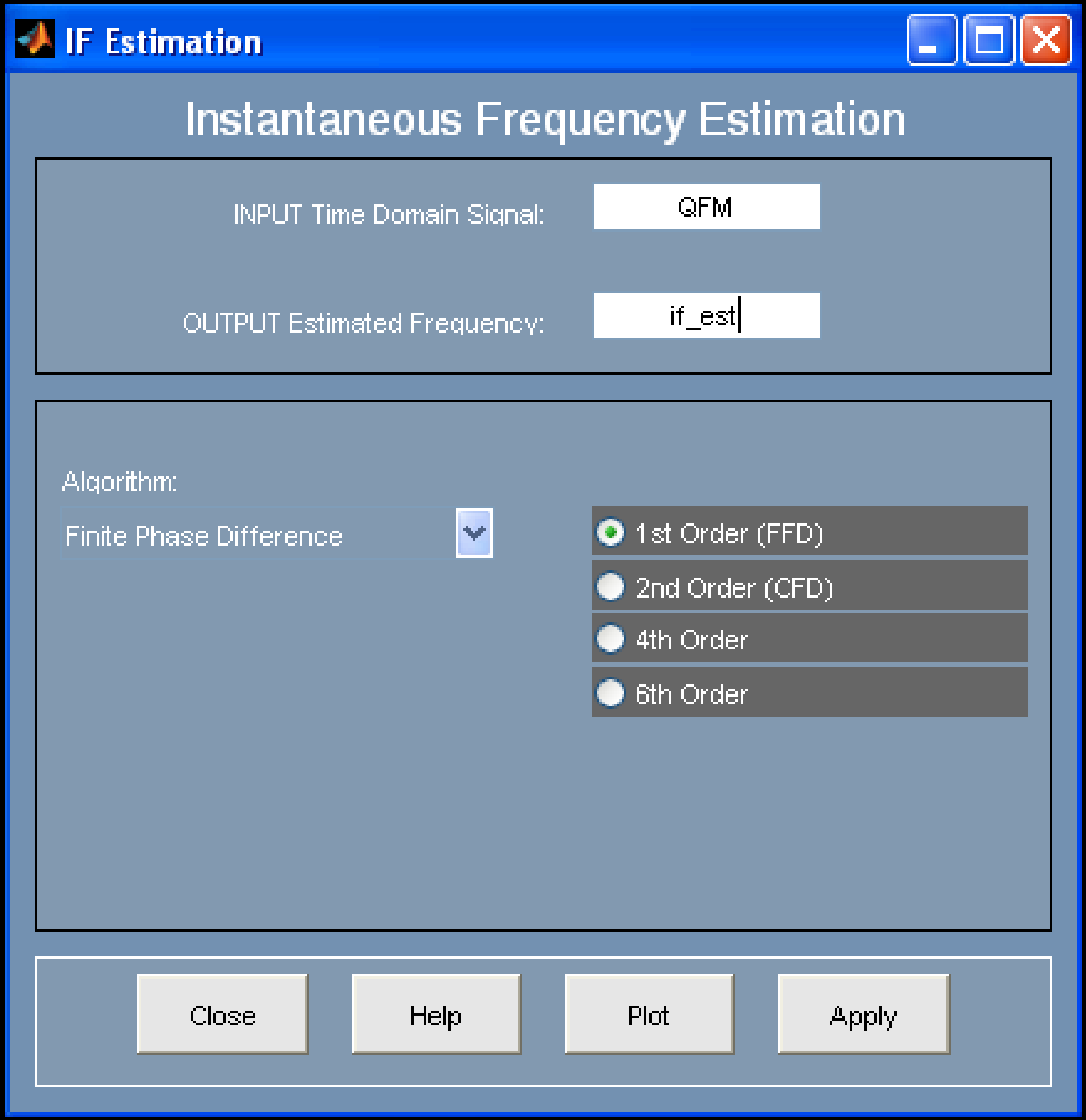
$$IF(t) = \frac{1}{2\pi}\frac{d\phi(t)}{dt}$$

- The IF can also be estimated using several differentiation schemes, adaptive techniques, the peaks of a TFD, and zero crossings.

TFSA IF Estimation

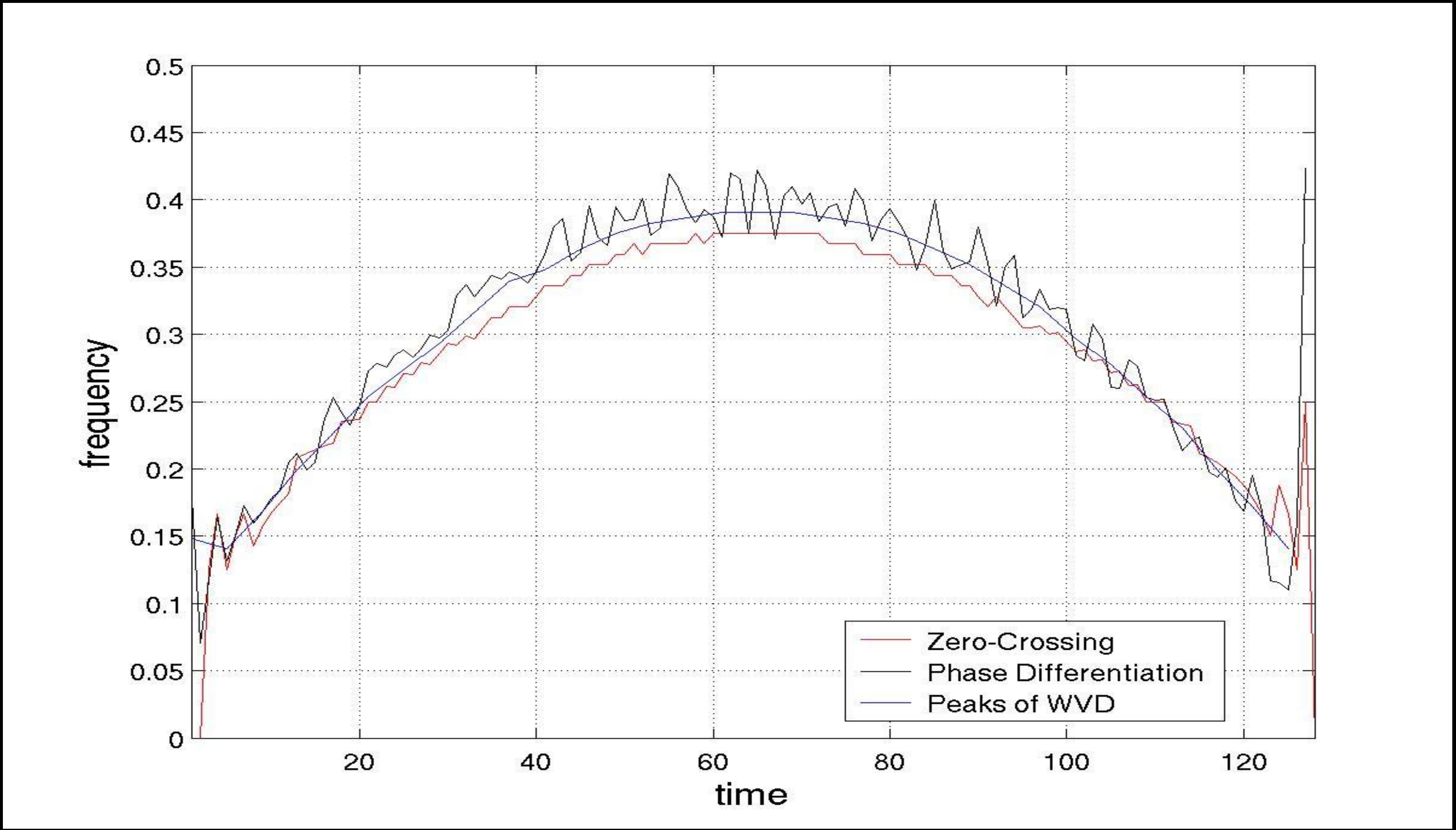
Estimate the IF of a quadratic FM in the presence of noise




IF Estimation
Instantaneous Frequency Estimation
INPUT Time Domain Signal:
QFM
OUTPUT Estimated Frequency:
if_est
Algorithm:
Finite Phase Difference
1st Order (FFD)
2nd Order (CFD)
4th Order
6th Order
Close
Help
Plot
Apply

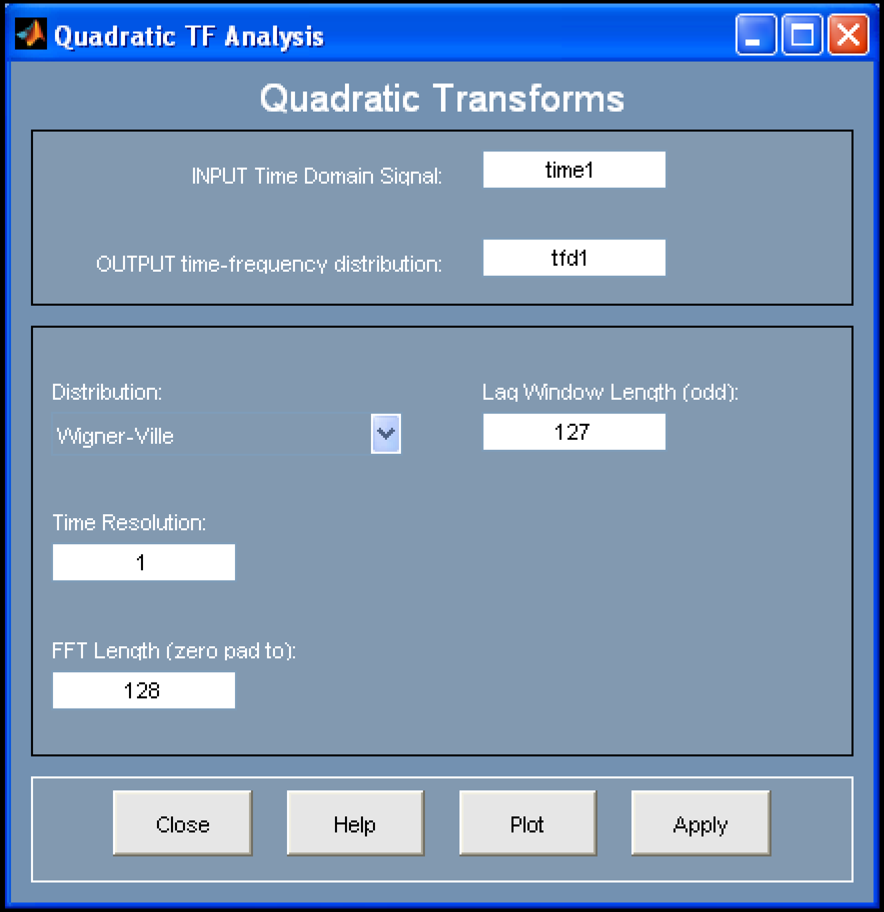
TFSA IF Estimation

```
>> plot(if_est1); hold; plot(if_est2,'r')); plot(if_est3)
```



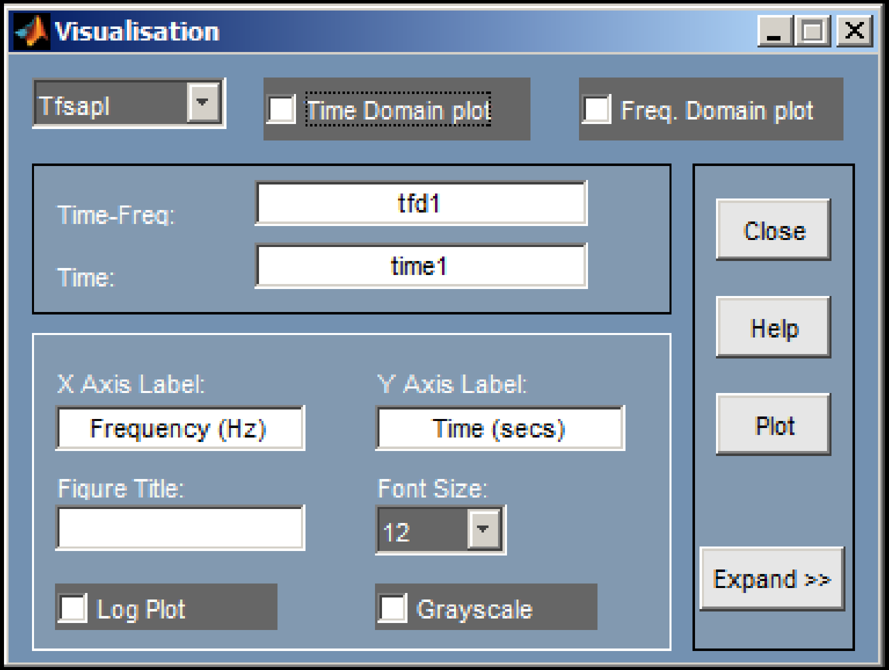
Quadratic TFDs

- Quadratic class of TFDs (Chapter **3, pp** 59)
  - Wigner-Ville
  - Smoothed WVD
  - Spectrogram
  - B-distribution
  - Modified B-distribution
  - Ext Modified B-distribution
  - CKD
  - MDD
  - …
- Cross WVD
- Ambiguity



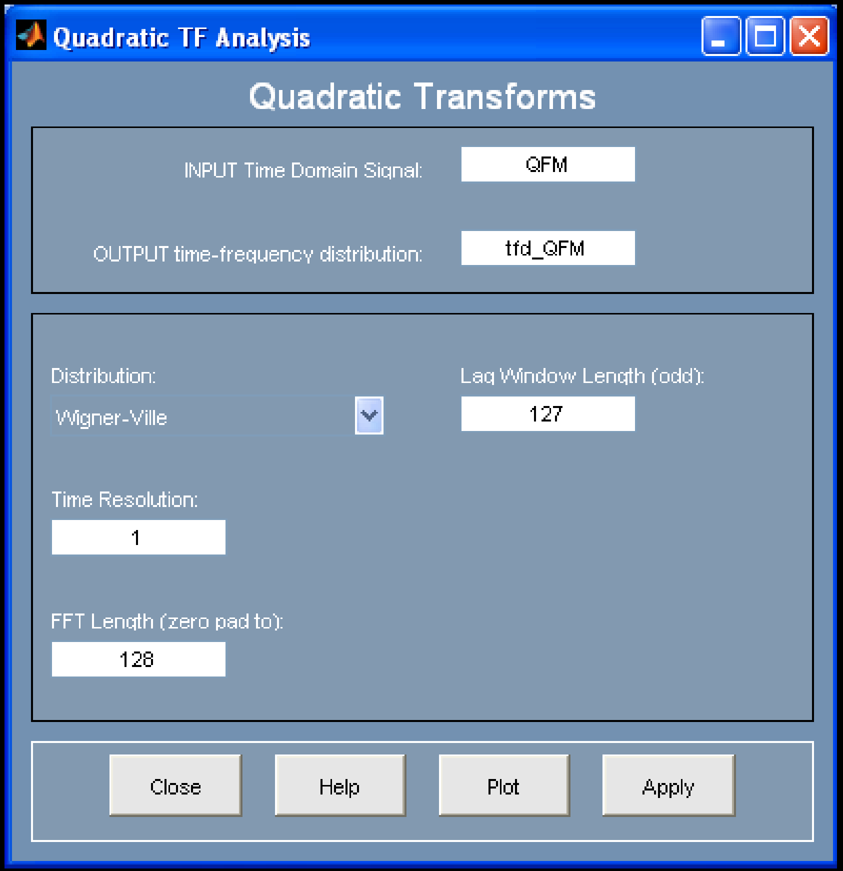
Visualisation

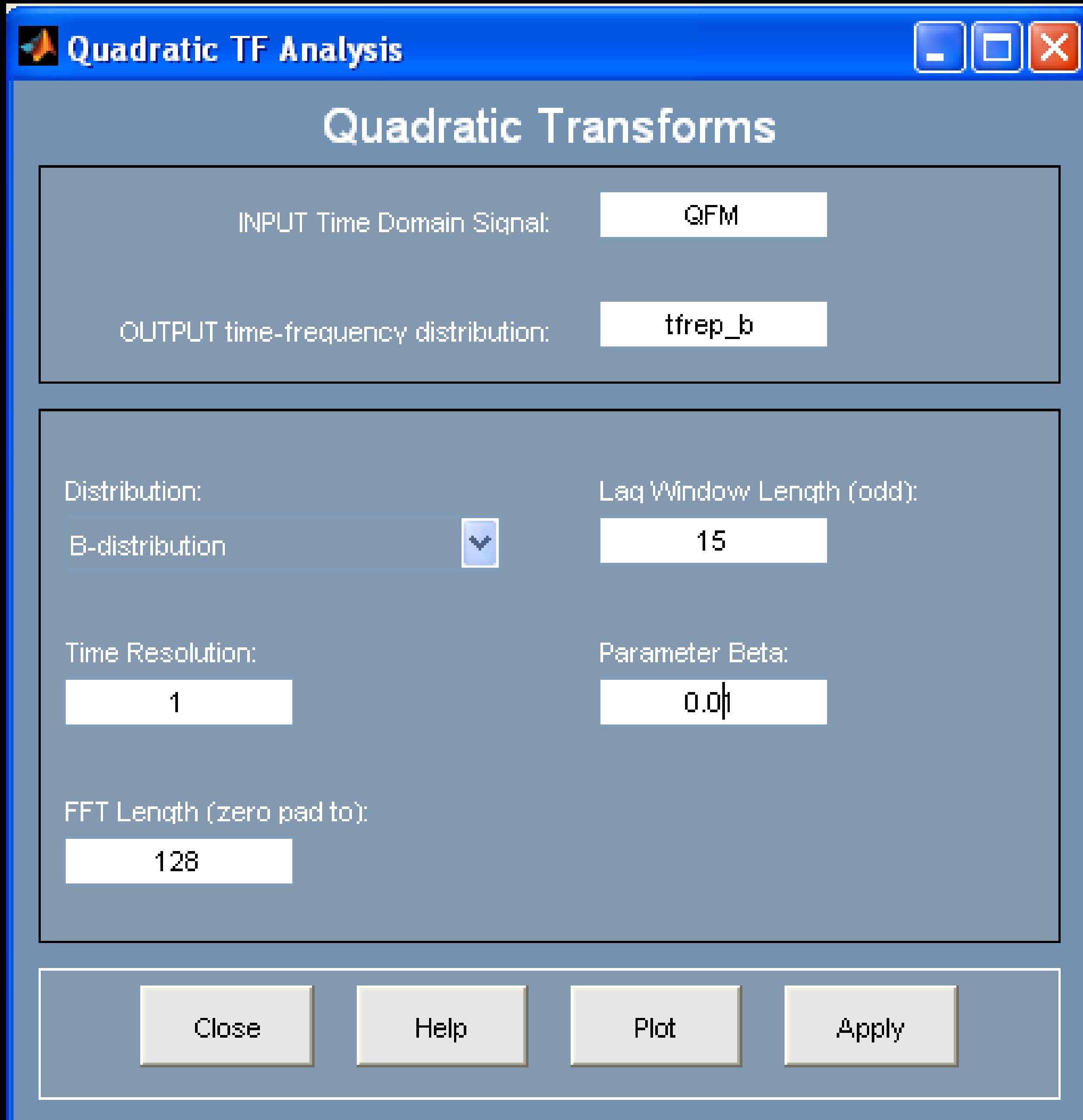
- Provides an array of visualisation options for the 3-D distribution (energy-time-frequency)
  - Specific TFD plot
  - Waterfall
  - Image
  - Logarithmic
  - Colormap

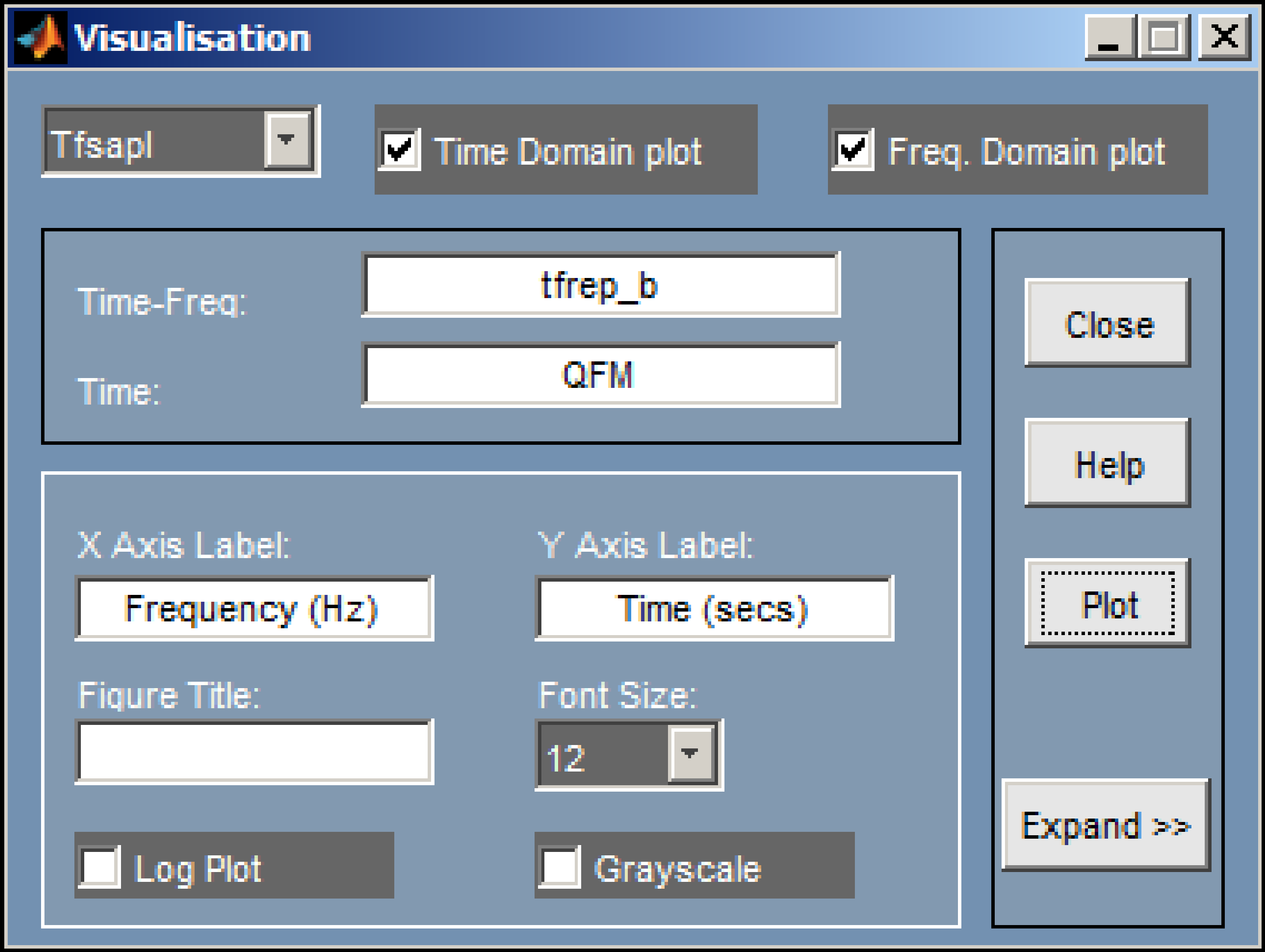


Quadratic TFD example

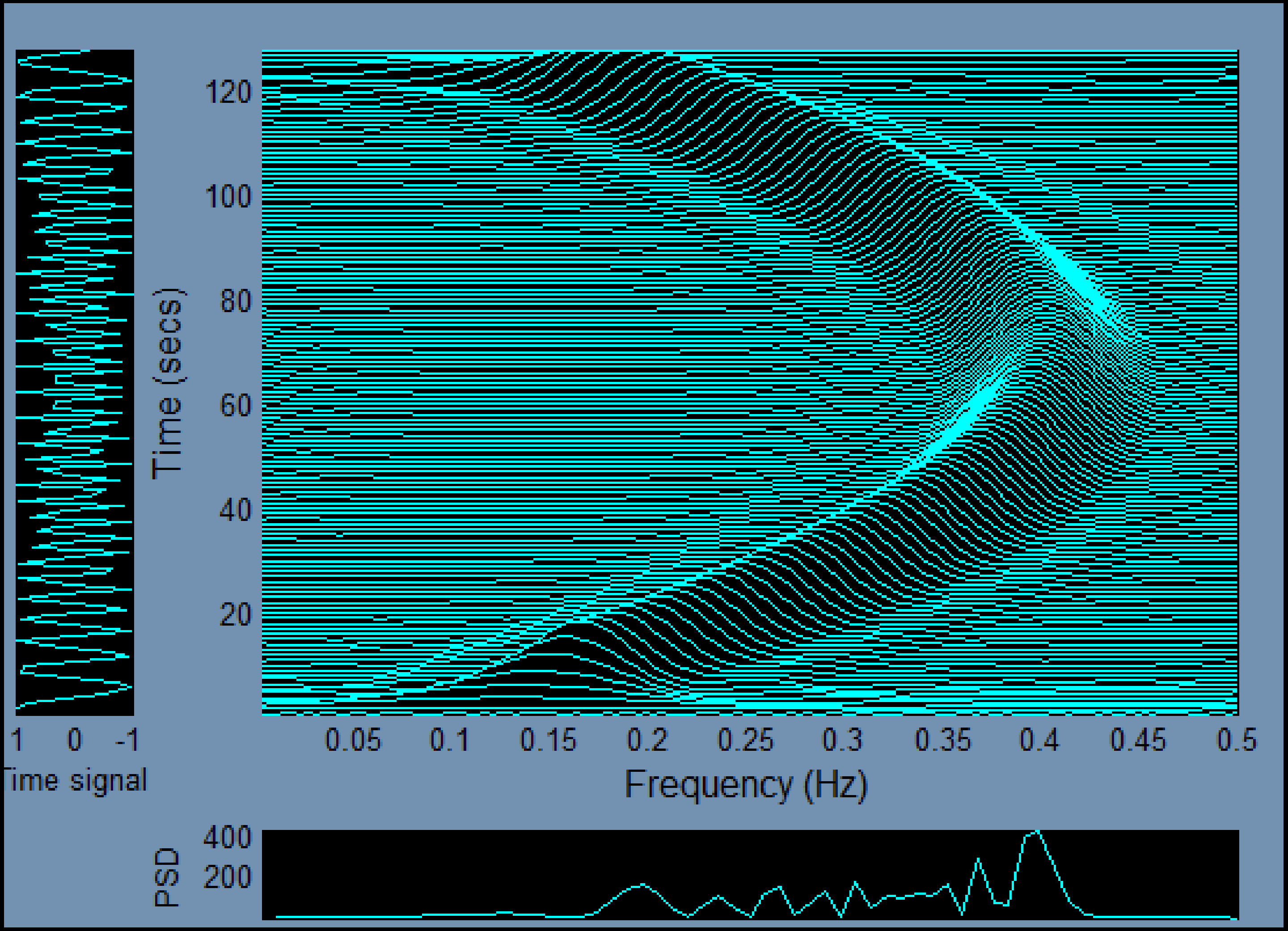
- Estimate the TFD of the quadratic FM signal.




Quadratic TF Analysis
Quadratic Transforms
INPUT Time Domain Signal:
QFM
OUTPUT time-frequency distribution:
tfrep_b
Distribution:
B-distribution
Lag Window Length (odd):
15
Time Resolution:
1
Parameter Beta:
0.01
FFT Length (zero pad to):
128
Close
Help
Plot
Apply

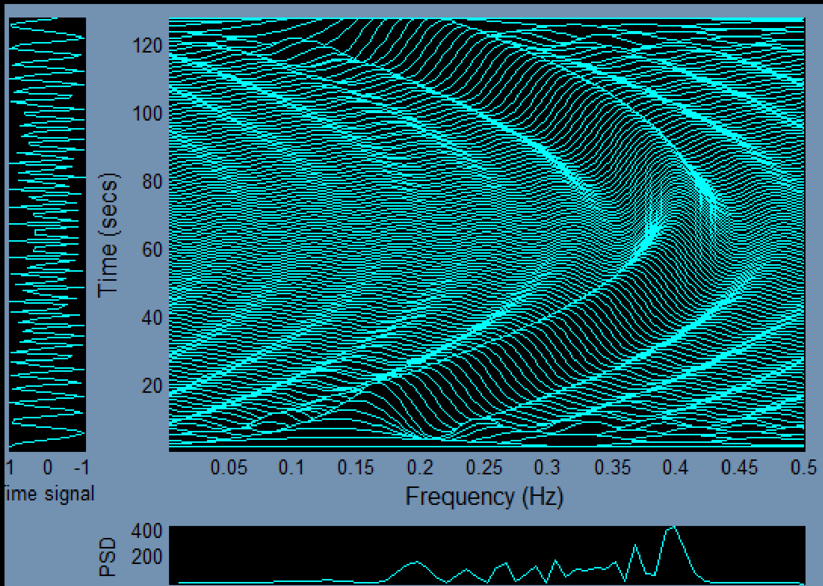

Visualisation
Tfsapl
Time Domain plot
Freq. Domain plot
Time-Freq:
tfrep_b
Time:
QFM
Close
Help
X Axis Label:
Y Axis Label:
Frequency (Hz)
Time (secs)
Plot
Figure Title:
Font Size:
12
Expand >>
Log Plot
Grayscale

Quadratic TFD example

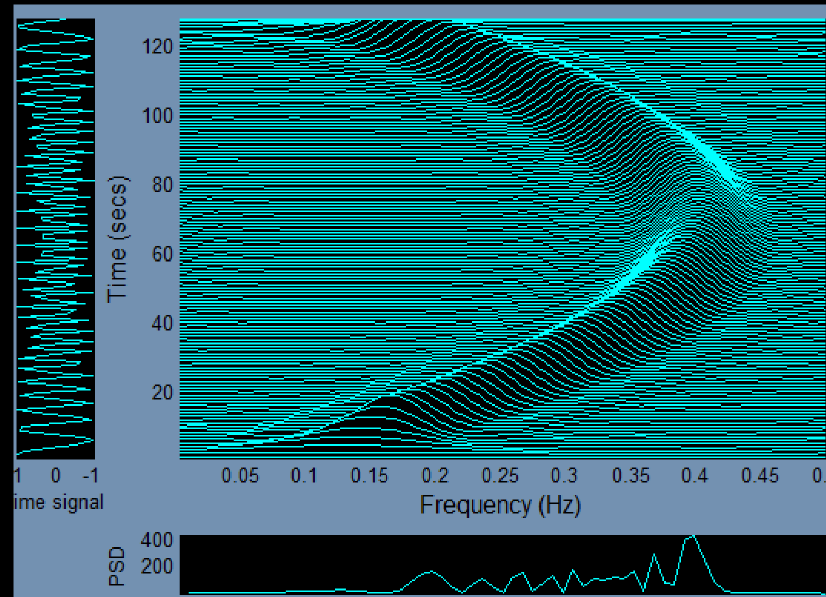


Quadratic TFD example

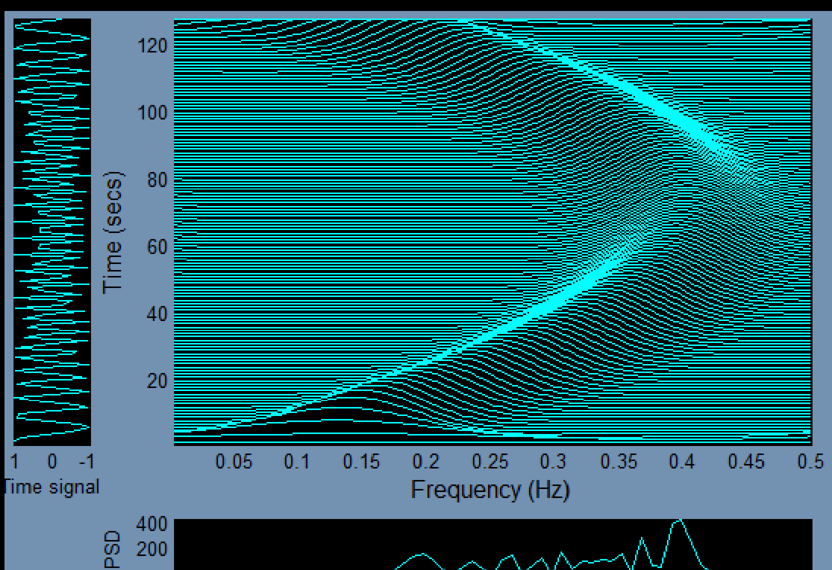
- WVD
  - win length = 15, nfft = 128, tres = 1
- Spectrogram
  - win length = 15, nfft = 128, tres = 1, smooth win = ‘hamm’, smooth win length = 15
- Choi-Williams
  - win length = 15, nfft = 128, tres = 1, sigma = 20
- B-distribution
  - win length = 15, nfft = 128, tres = 1, beta = 0.01



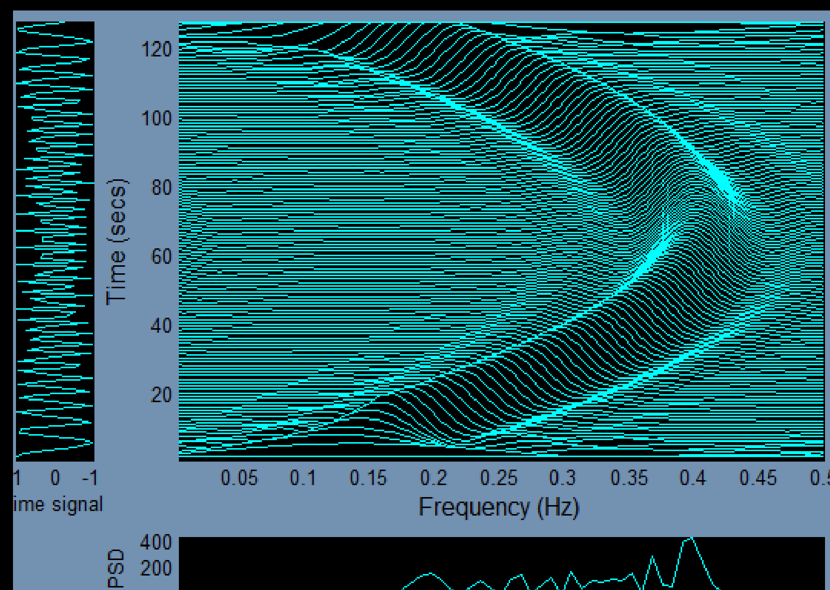
Wigner-Ville distribution



B-distribution



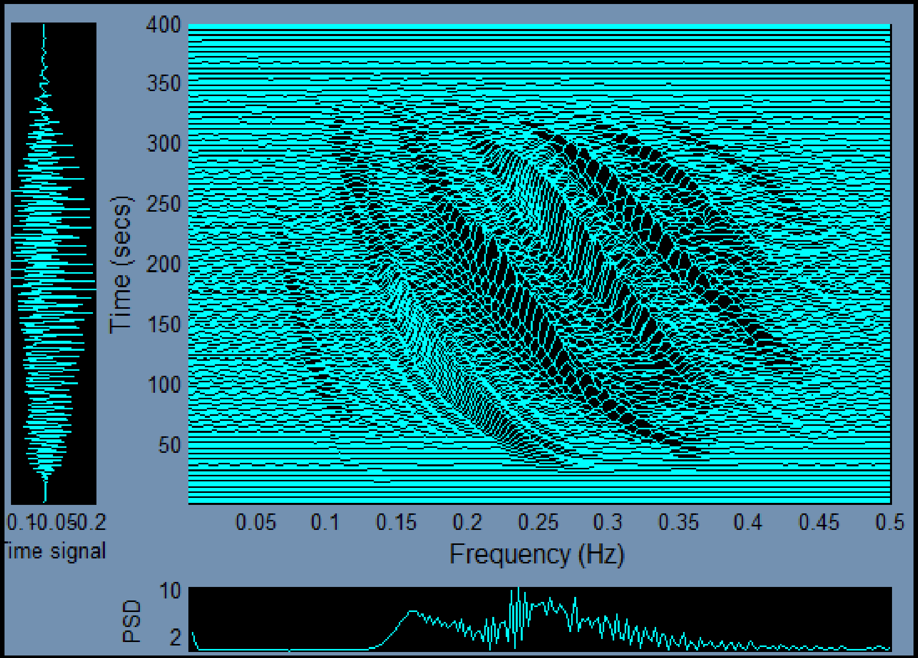
Spectrogram



Choi-Williams

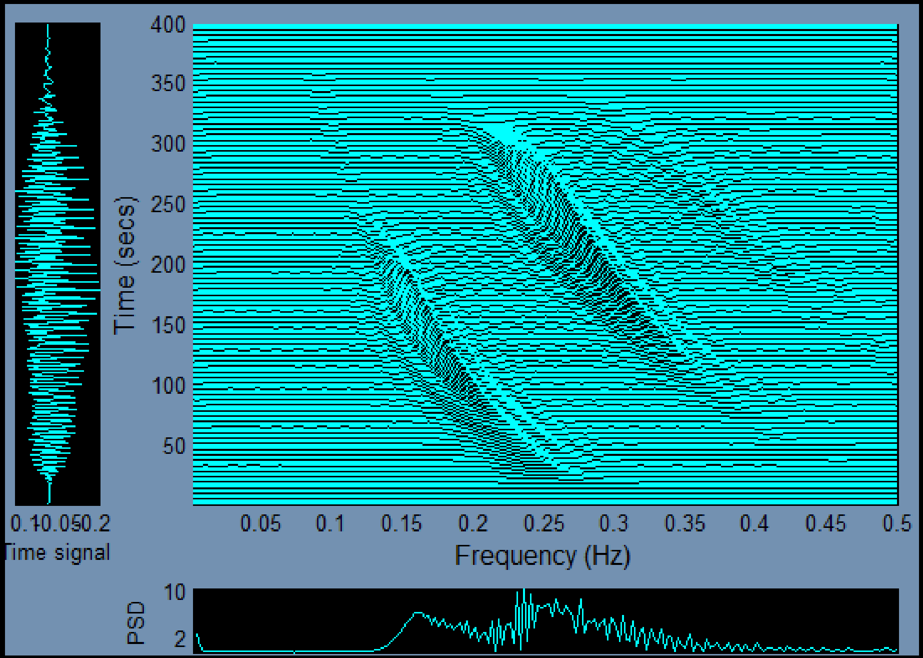
Quadratic TFDs Example

- Bat echolocation



Wigner-Ville distribution

win len = 63, nfft = 256,
tres = 2



Modified B-distribution

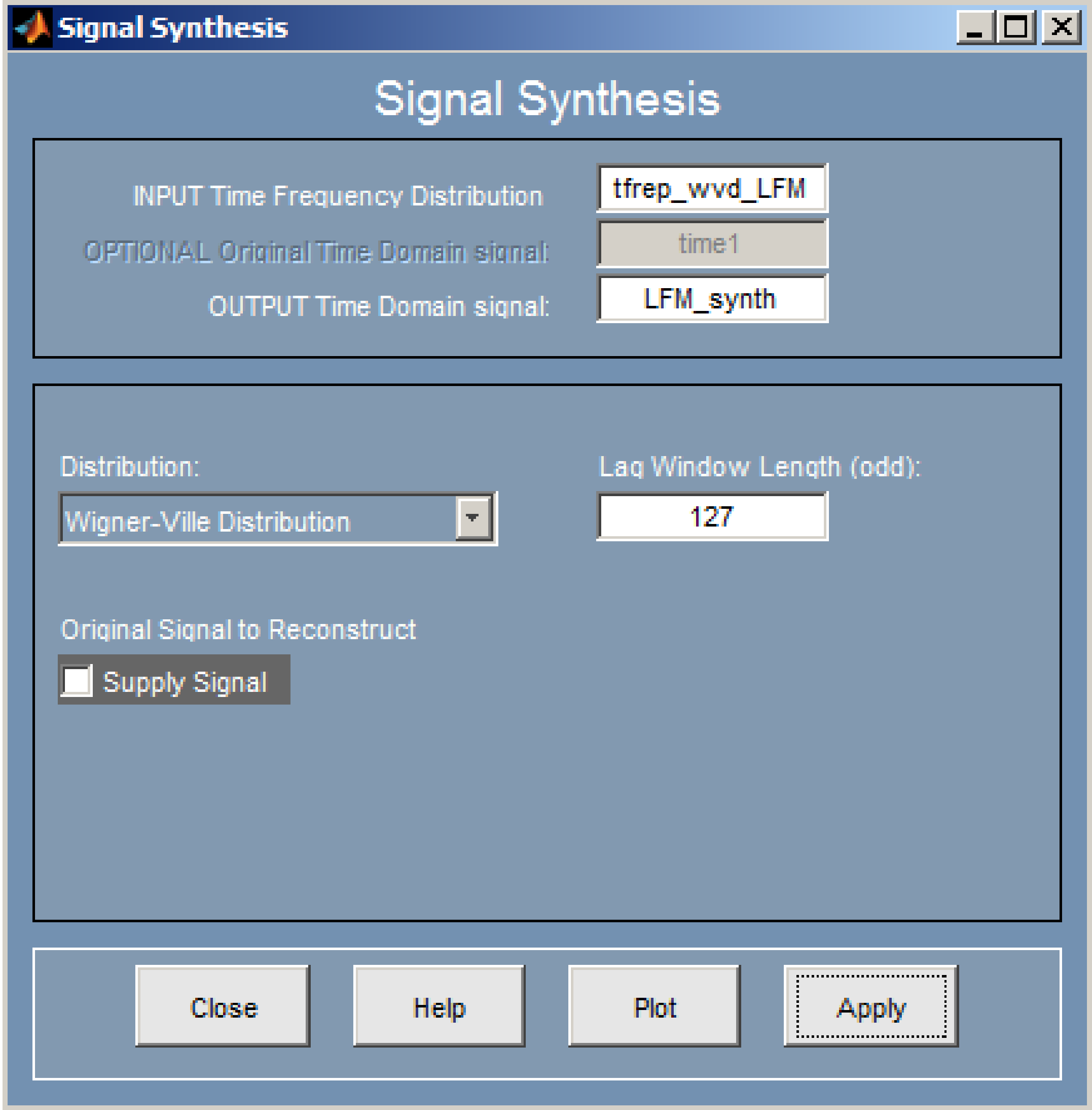
win len = 63, nfft = 256,
tres = 2, beta = 0.01

Signal Synthesis

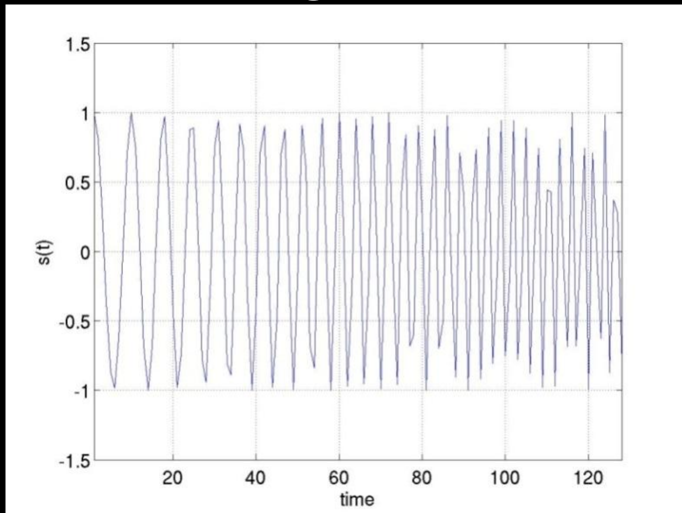
- Signal Synthesis
  - STFT (overlap and add)
  - STFT (IDFT)
  - Modified STFT
  - Modified Spectrogram
  - WVD
- Time frequency filtering

Example

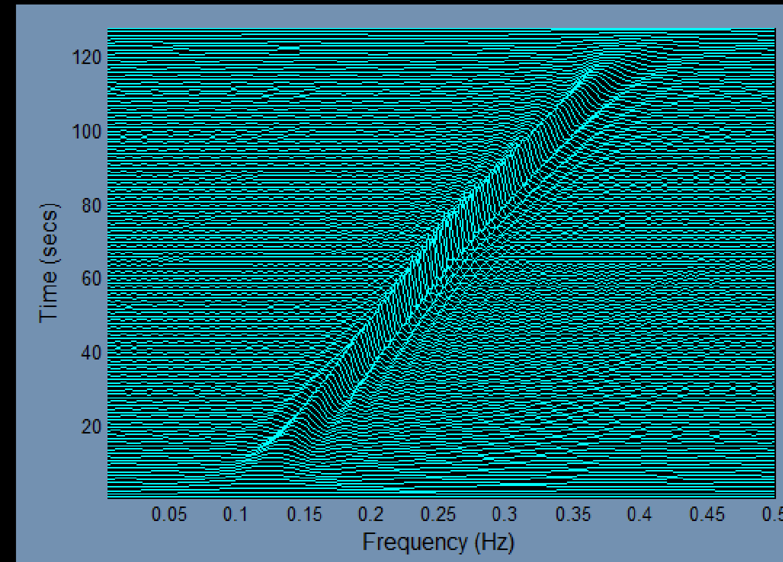
- Perform signal synthesis on a WVD of a linear FM signal
  - – Generate LFM (f_{range} = 0.1 – 0.4, len = 128)
  - – Find TFD using WVD (tres = 1, win len = 127)
  - – Synthesise using WVD method
  - – Find TFD of synthesised window


Signal Synthesis
Signal Synthesis
INPUT Time Frequency Distribution
tfrep_wvd_LFM
OPTIONAL Original Time Domain signal:
time1
OUTPUT Time Domain signal:
LFM_synth
Distribution:
Wigner-Ville Distribution
Lag Window Length (odd):
127
Original Signal to Reconstruct
Supply Signal
Close
Help
Plot
Apply

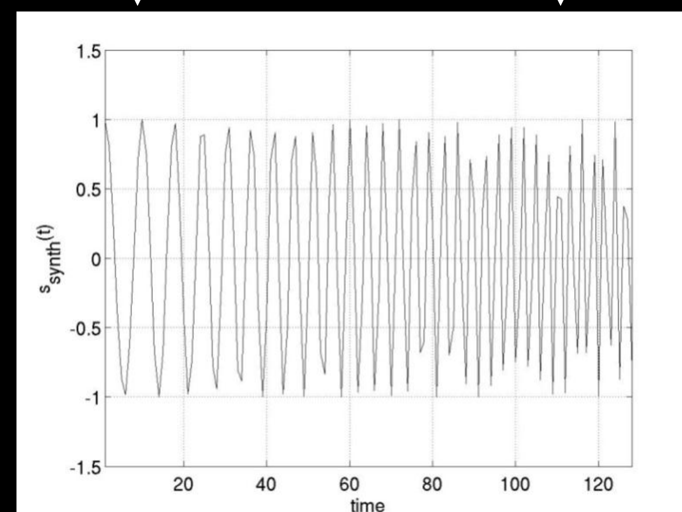
Signal



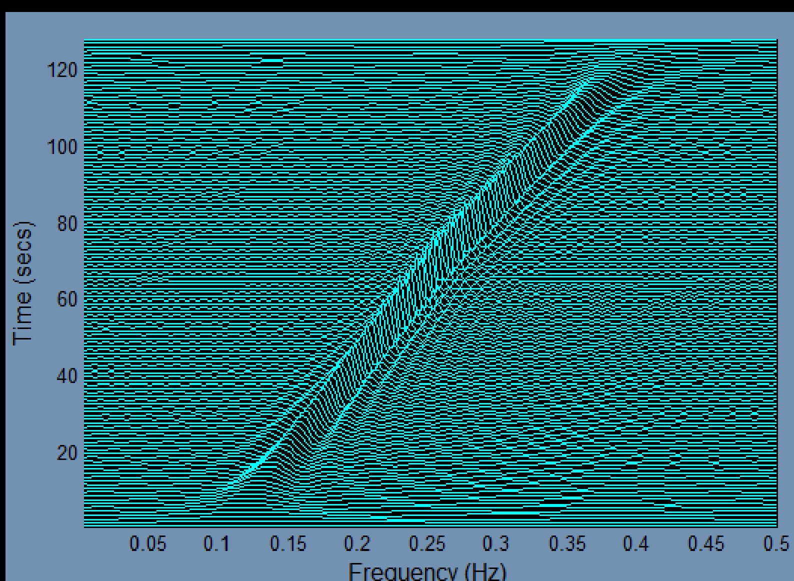
WVD of Signal



Synthesis

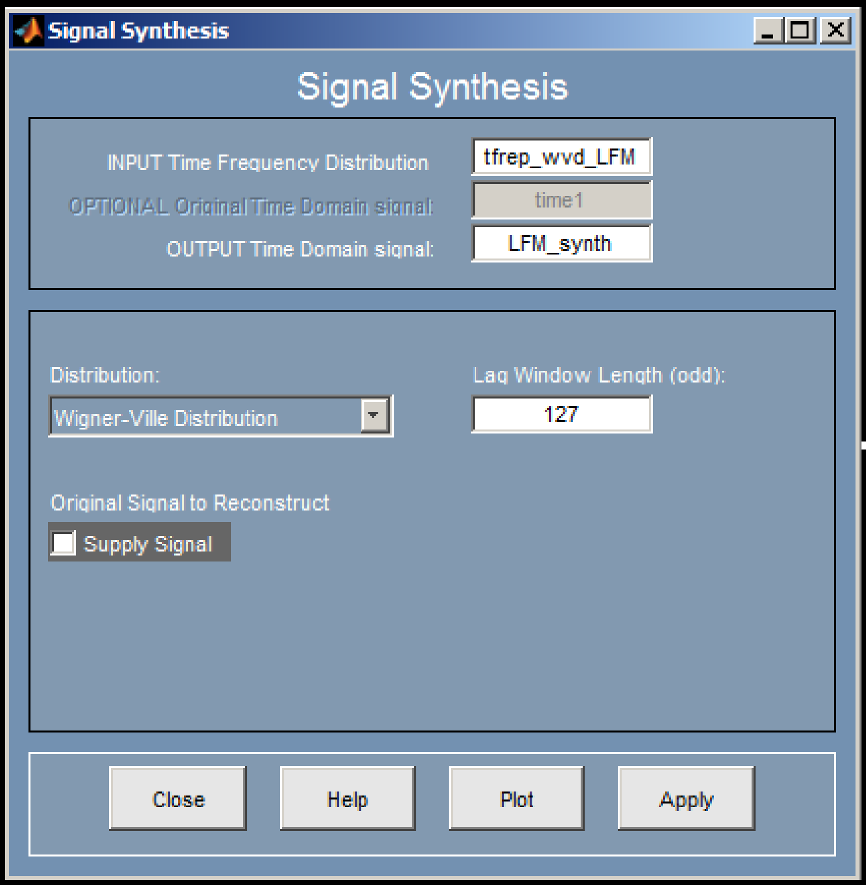


WVD of synthesised signal

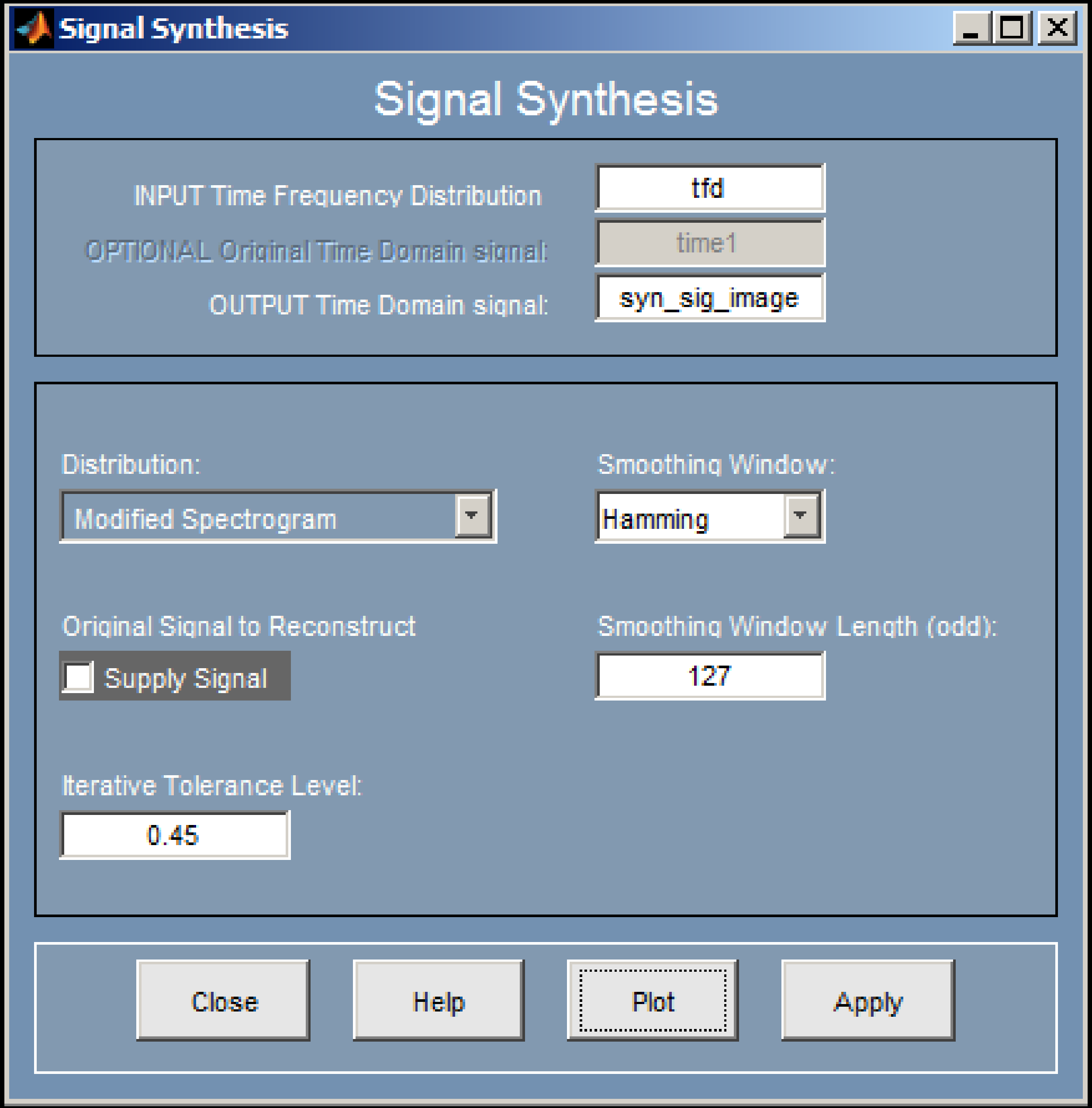


Signal Synthesis

```
>> tfd =double(rgb2gray(imread('signal1.jpg','jpg')))';
```

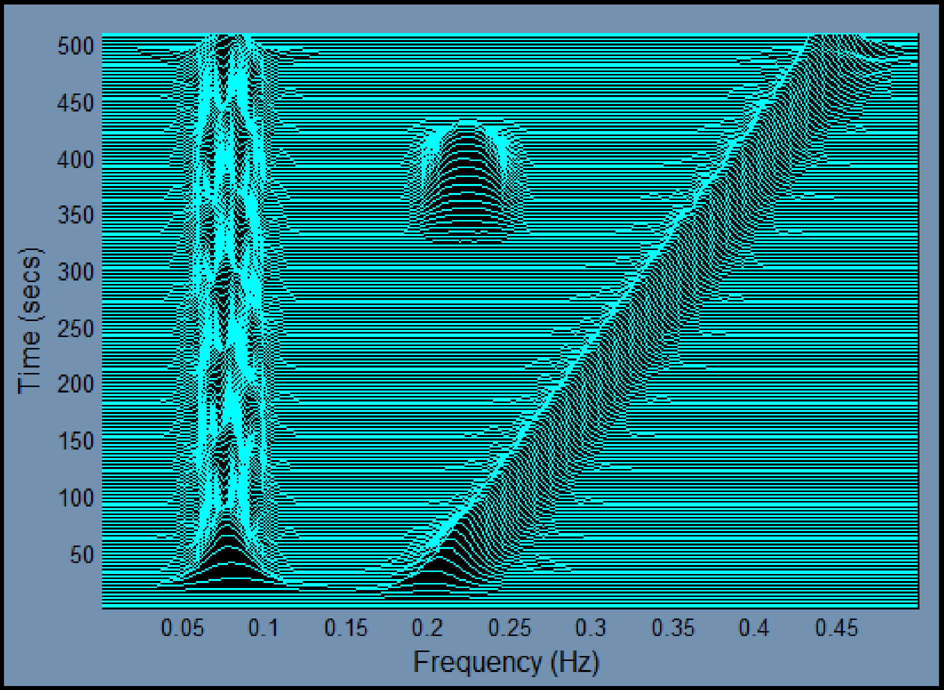


TFD


Signal Synthesis
Signal Synthesis
INPUT Time Frequency Distribution
tfd
OPTIONAL Original Time Domain signal:
time1
OUTPUT Time Domain signal:
syn_sig_image
Distribution:
Modified Spectrogram
Smoothing Window:
Hamming
Original Signal to Reconstruct
Supply Signal
Smoothing Window Length (odd):
127
Iterative Tolerance Level:
0.45
Close
Help
Plot
Apply

Signal Synthesis

Modified Spectrogram



Original TFD

Synthesised TFD

TFD generated using the spectrogram (win len = 127, tres = 3, smth win = ‘hamm’, smth win len = 127, nfft = 512)

Signal Synthesis

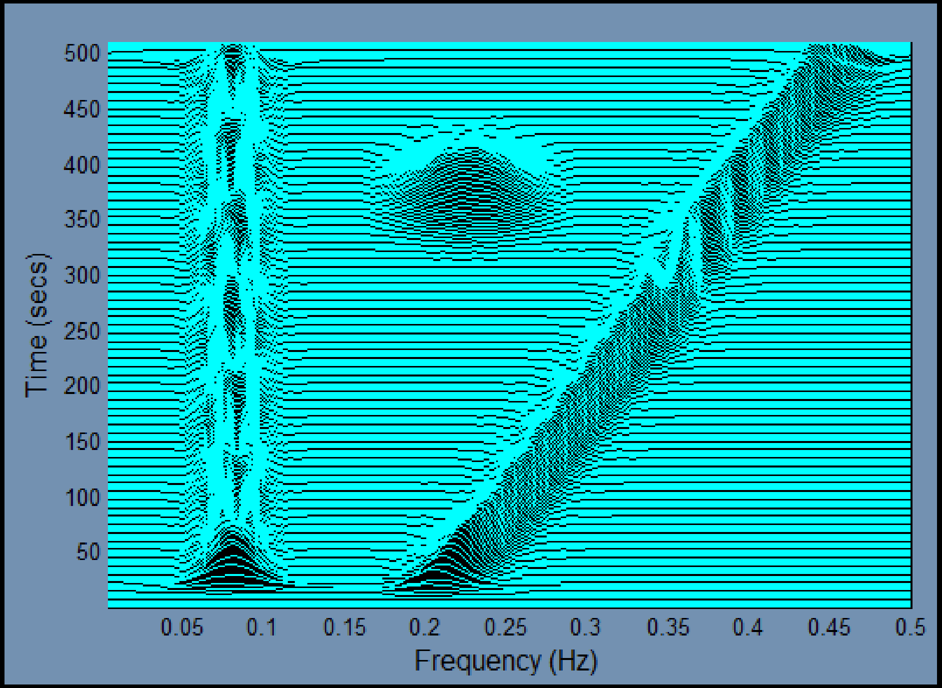
- Try for ‘signal2.jpg’ with the same parameters as the previous example

```
>> tfd =double(rgb2gray(imread('signal2.jpg','jpg')))';
```

Signal Synthesis

Modified Spectrogram

TFD (signal2.jpg)



Synthesised TFD

Other tools

- Scale analysis
  - Wavelet Transform
    - Daubauchies
- Toolbox Demo
- Higher Order TFDs
- Power Spectral Estimation
  - Periodogram