


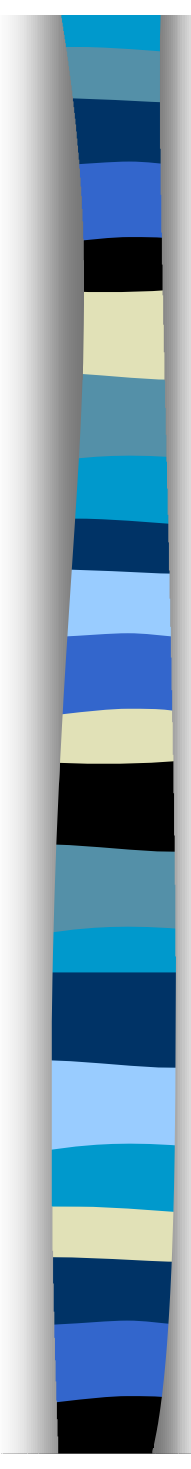
SIGnal Processing and SENSor Laboratory (SIGSENS)



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Respiration Signal Extraction from Heart Rate



Introduction

- Highly-integrated, multi-function sensing
- Constraints on biomedical hardware
- Processing of the cardiac signal



Background

■ Respiration Signal Extraction

- Heart rate (HR) available from oximeter
- Respiratory frequency available by demodulation of heart rate
- Processing for respiration results in non-uniformly sampled modulating signal



Background

■ Pulse Oximeter

- Measures percent oxygen, oxygen saturation level, and heart-rate
- Optical sources:
 - 660nm - Peak response to Hemoglobin (or, de-oxygenated blood)
 - 910nm - Peak response to Oxy-hemoglobin
- As oxygen saturation (S_aO_2) increases, the absorbency of light increases at 910nm and decreases at 660nm



Background

■ System Requirements

- Pulse oximeter with respirometer
- Lightweight, non-invasive sensor for physiological monitoring
- Extraction of maximum information from single sensor
- Isolate and extract the effects of respiration on heart rate



Background

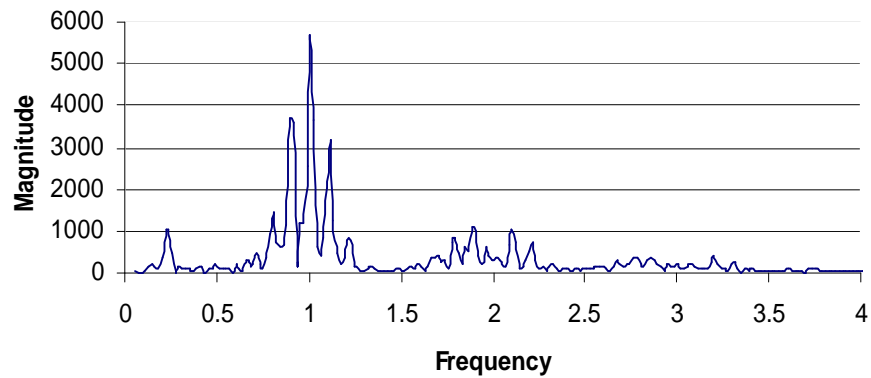
- Synthetic processing based on frequency modulation (FM) communications model:

$$x[n] = A * \cos\{(w_c/F_s)*n\} + (1/w_m)*\sin[(w_m/F_s)*n]$$

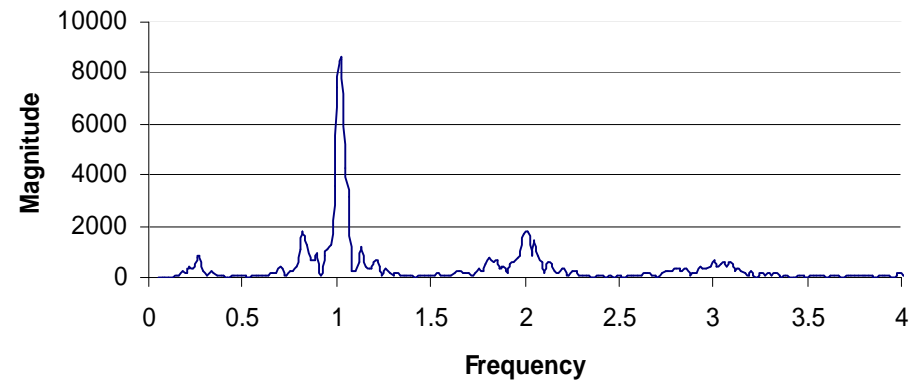
where, $w_c = 2*\pi*1.25$ and $w_m = 2*\pi*f_m$
and $f_m = .1, .2, \text{ or } .4$ Hz

Spectrum of Unprocessed Heart Rate Data

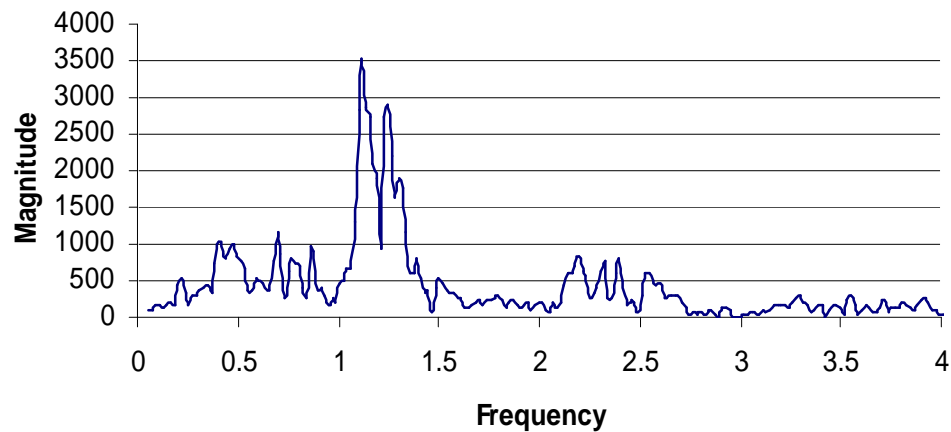
FFT of 6 BPM Heart Rate Data



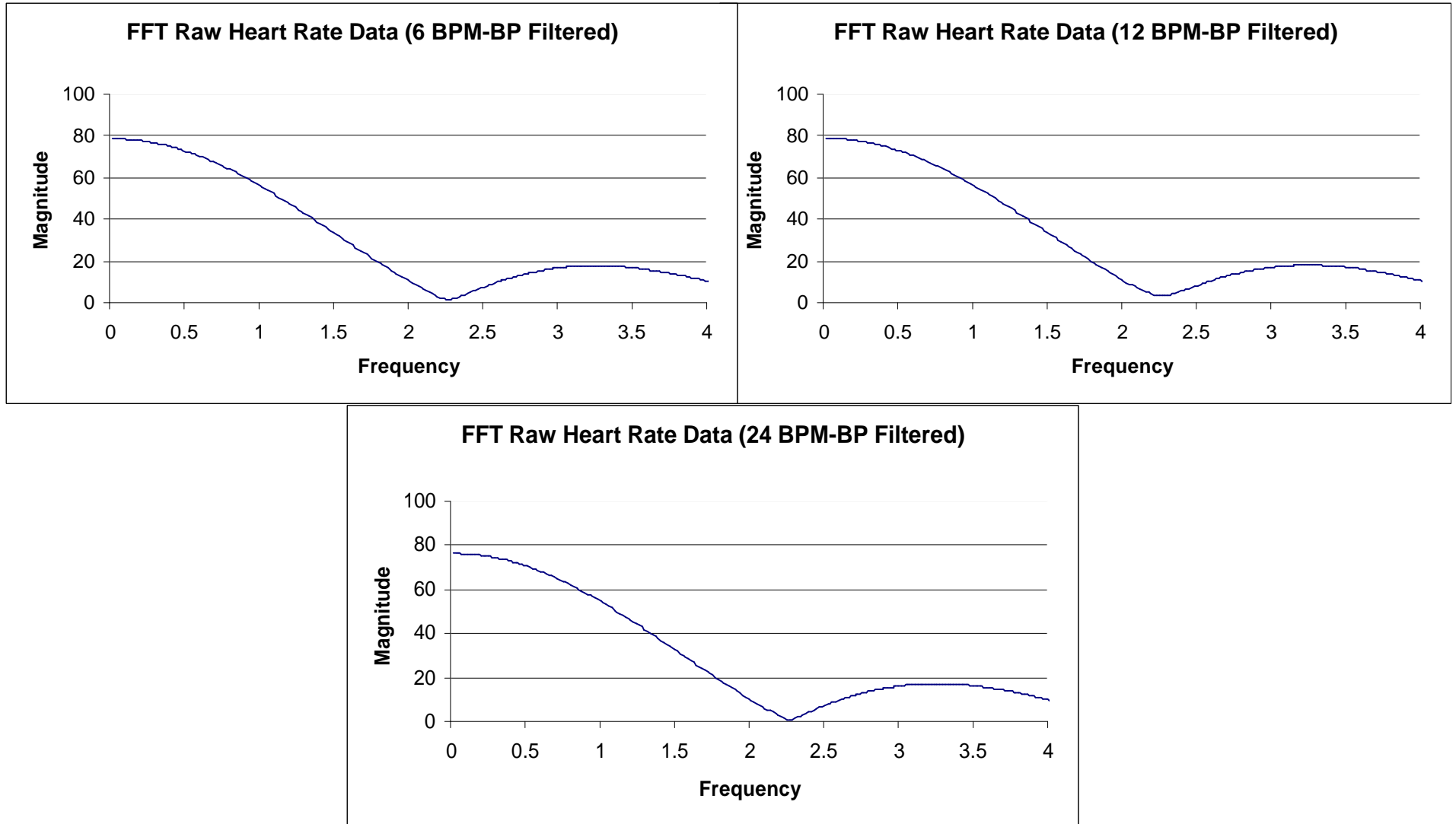
FFT of 12 BPM Heart Rate Data



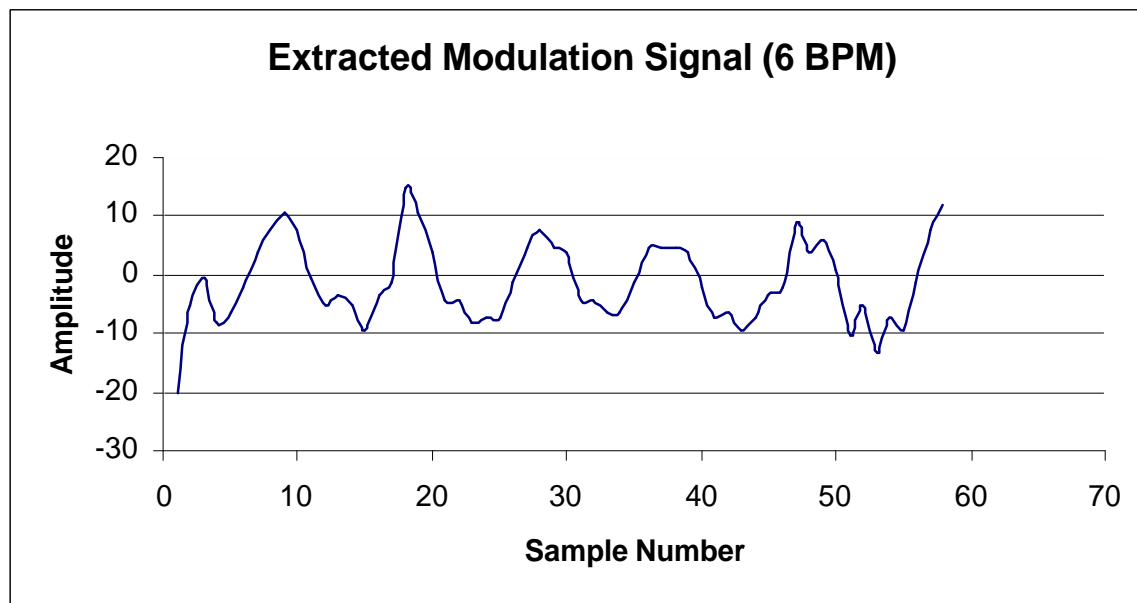
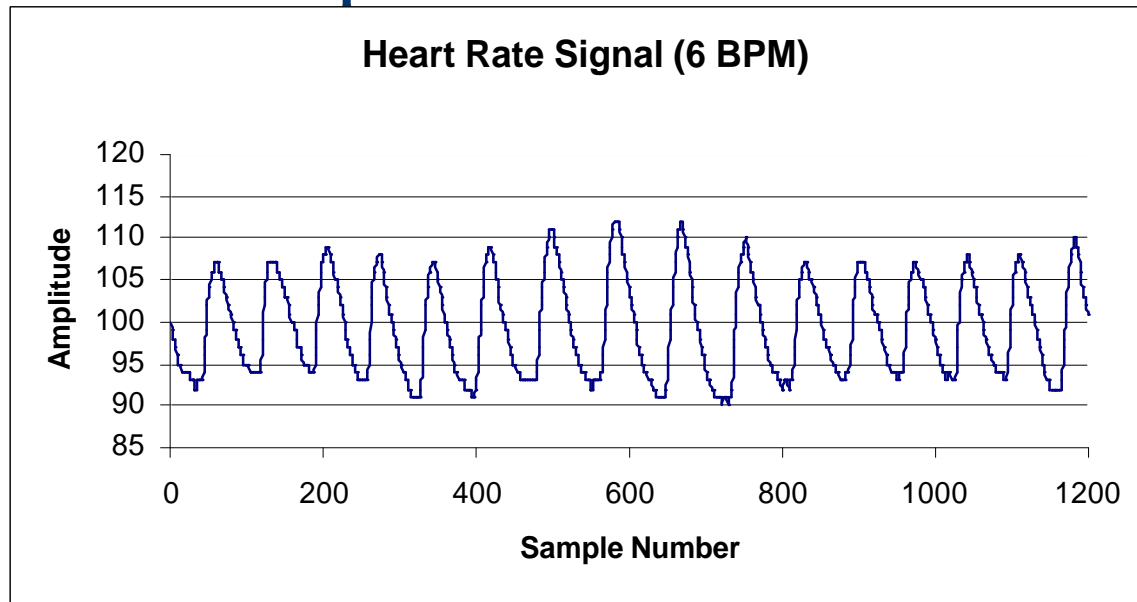
FFT of 24 BPM Heart Rate Data



Spectrum of Band-Passed Filtered (0.05 -0.6 Hz) Raw Heart Rate Data

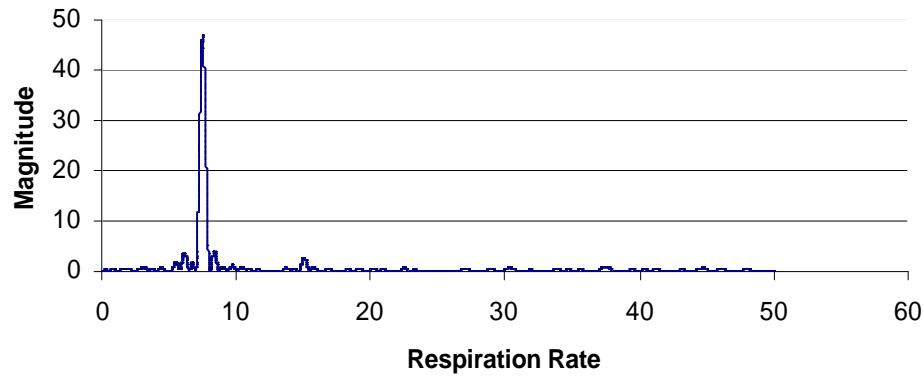


HR and Modulating Signal, 6 BPM, Experimental Data

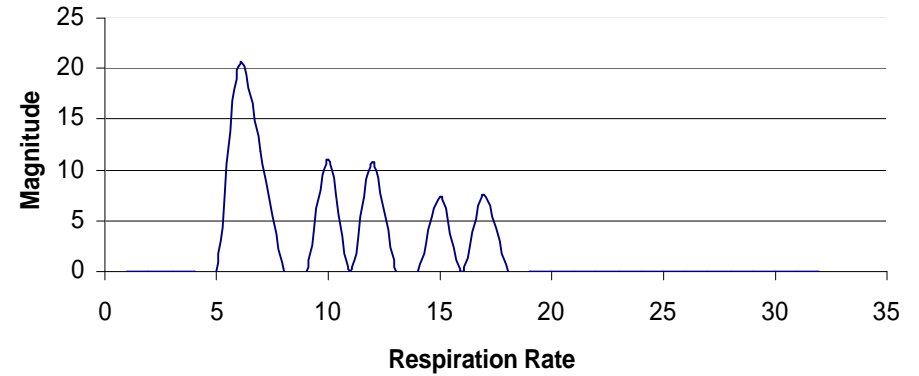


Spectrum Analysis, 6 BPM

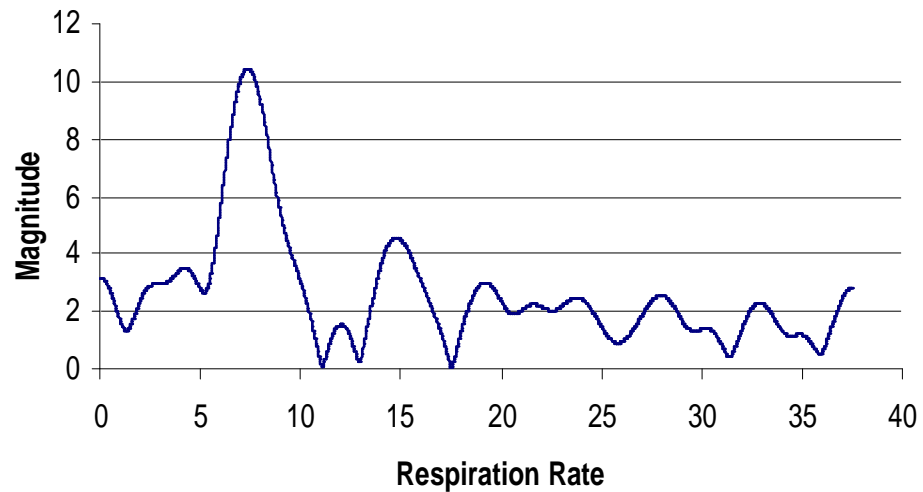
L-S Periodogram, 6 BPM



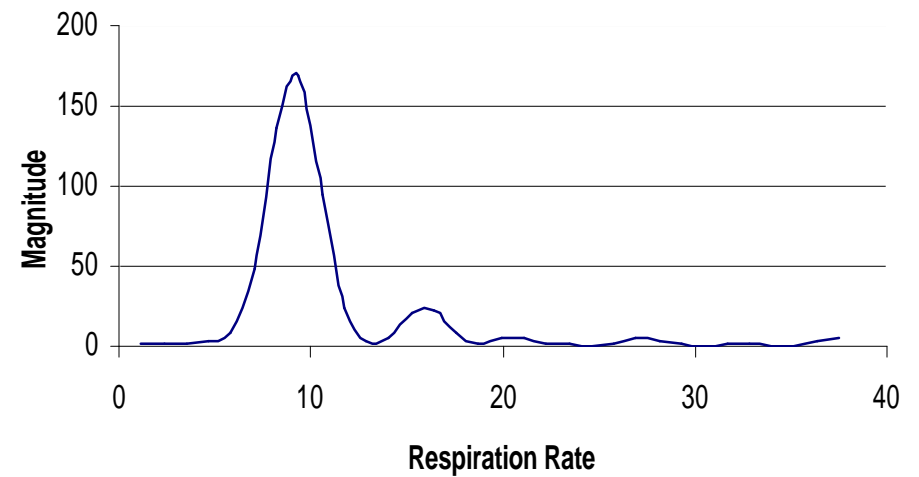
DWT, 6 BPM



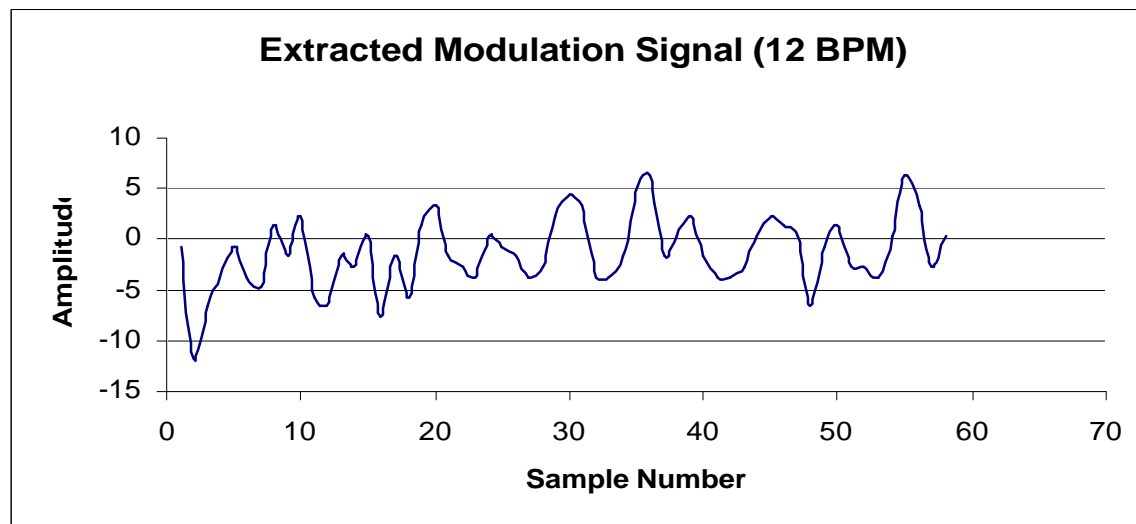
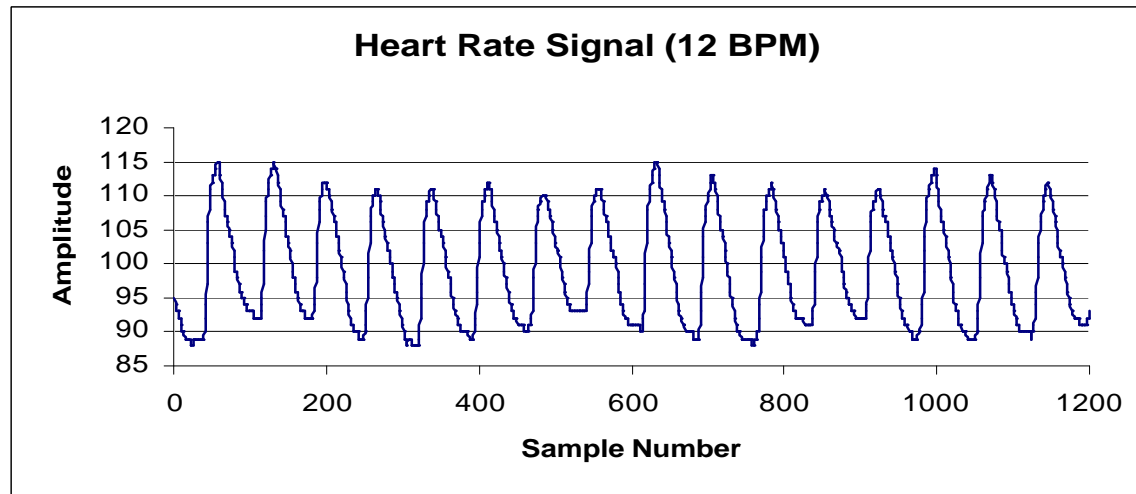
FFT, 6 BPM



PSD, 6 BPM

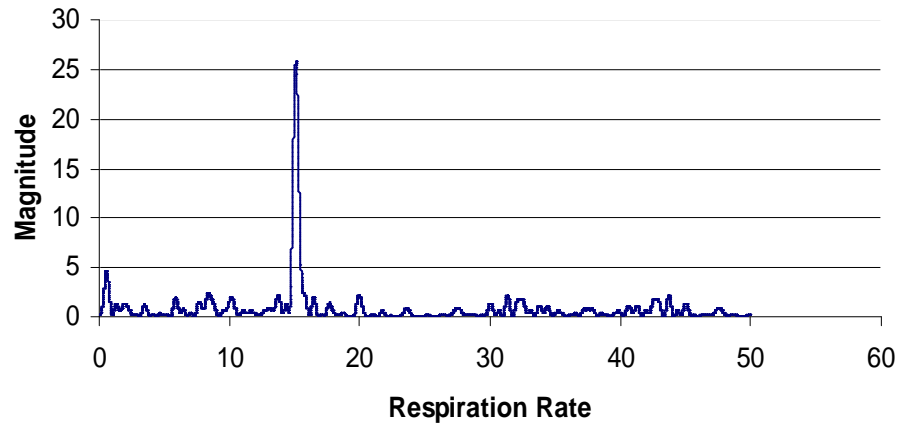


HR and Modulating Signal, 12 BPM, Experimental Data

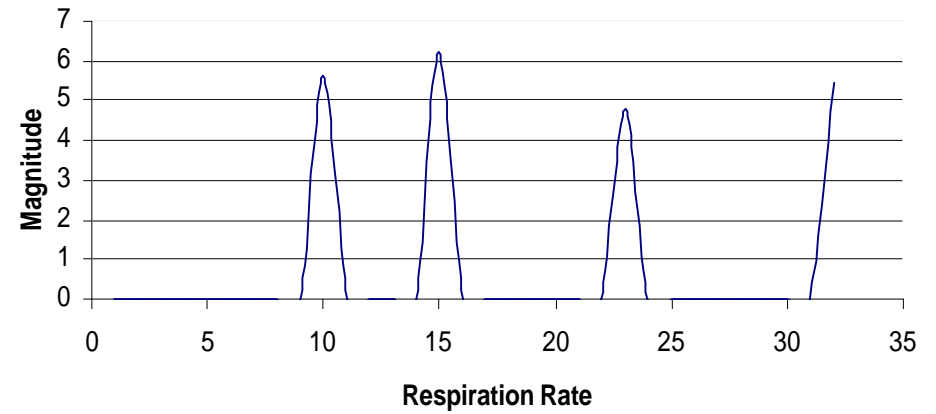


Spectrum Analysis, 12 BPM

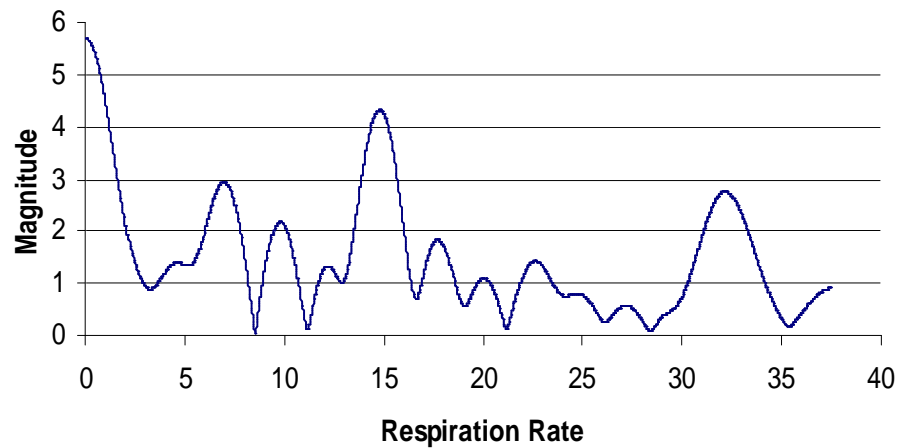
L-S Periodogram, 12 BPM



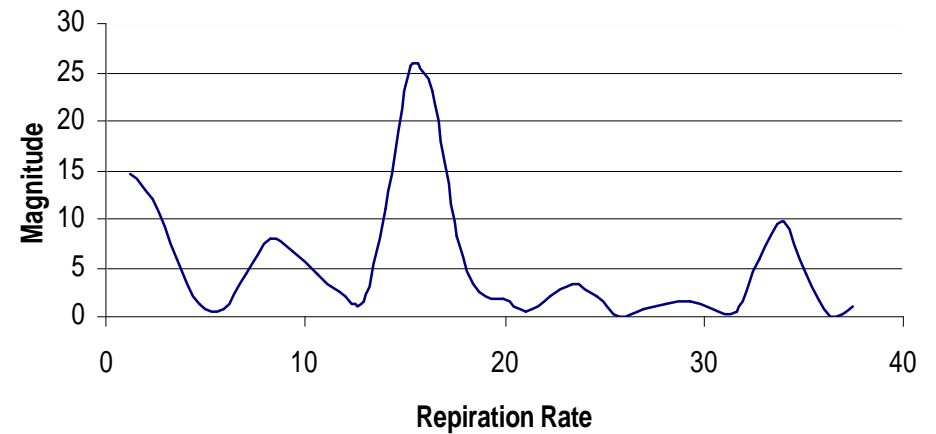
DWT, 12 BPM



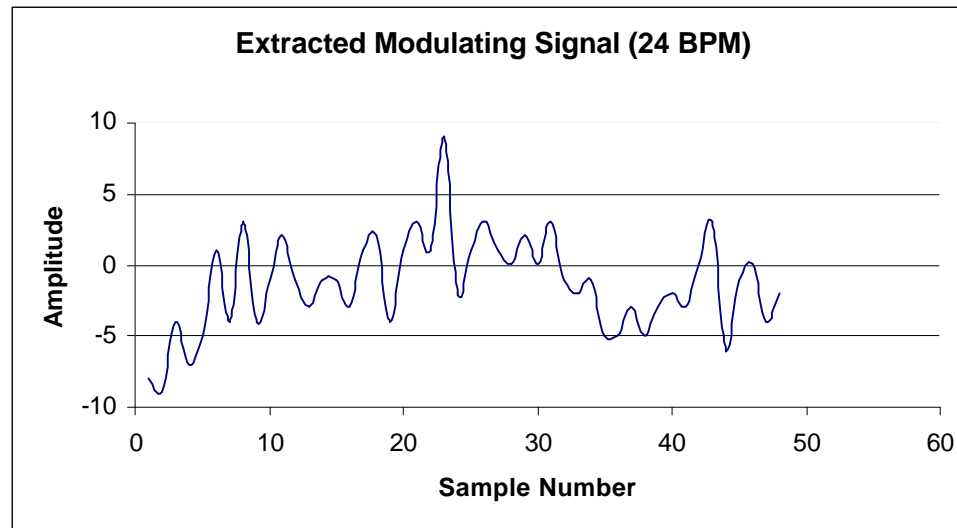
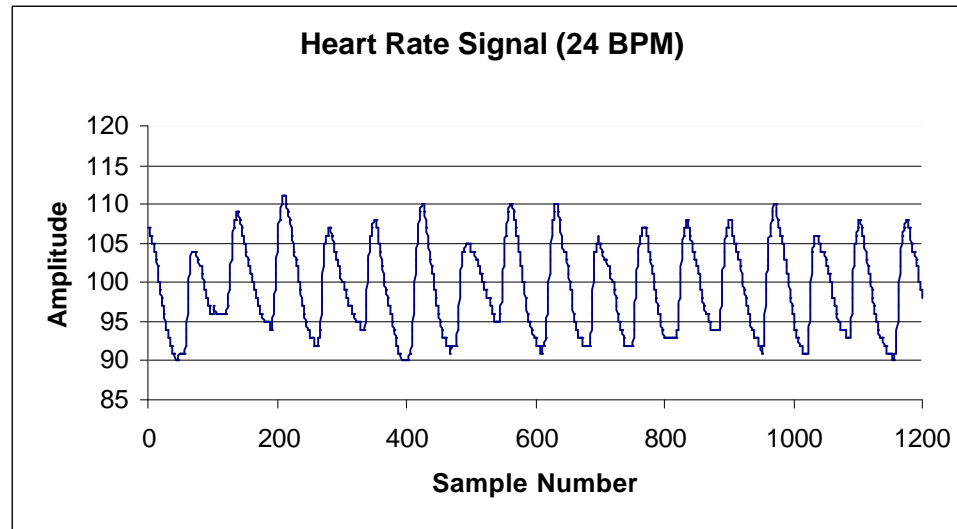
FFT, 12 BPM



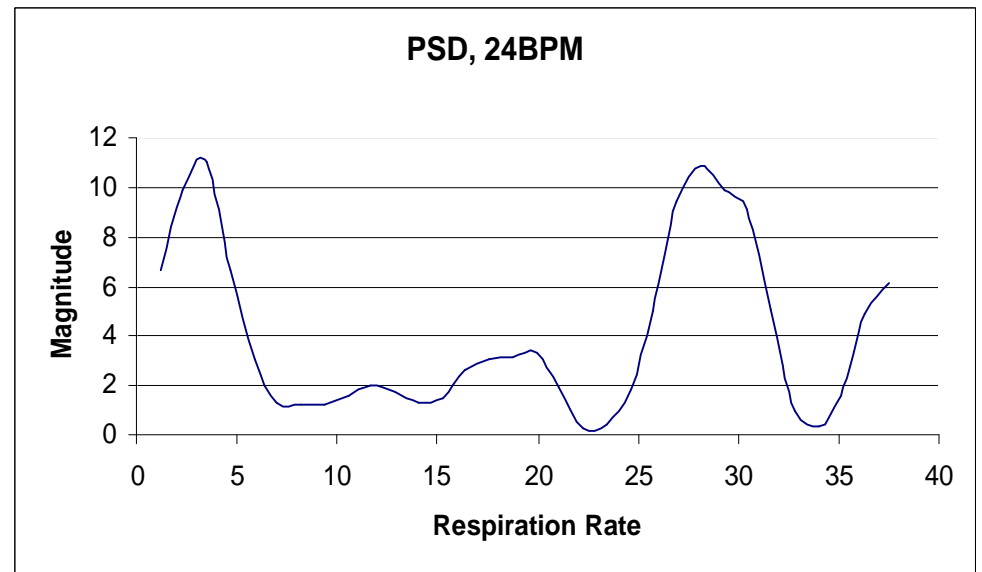
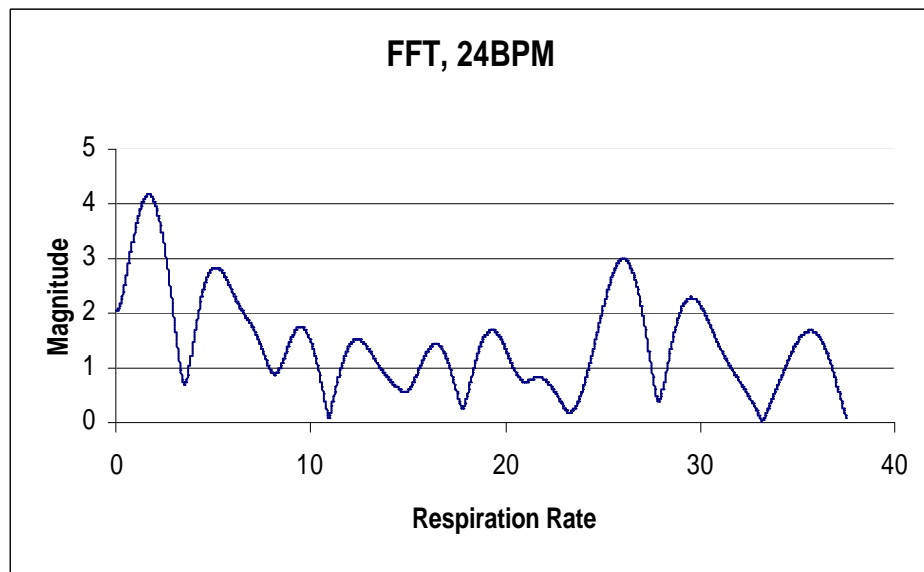
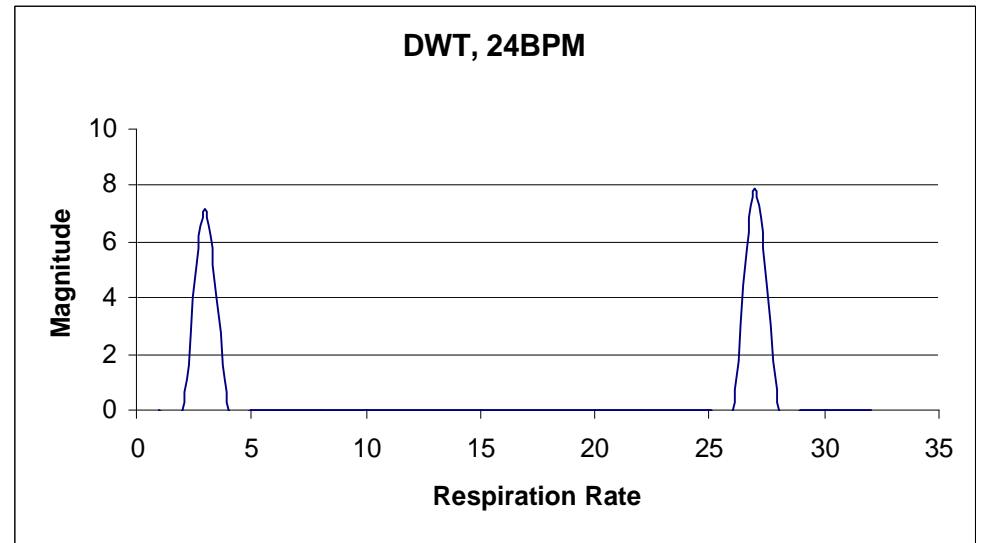
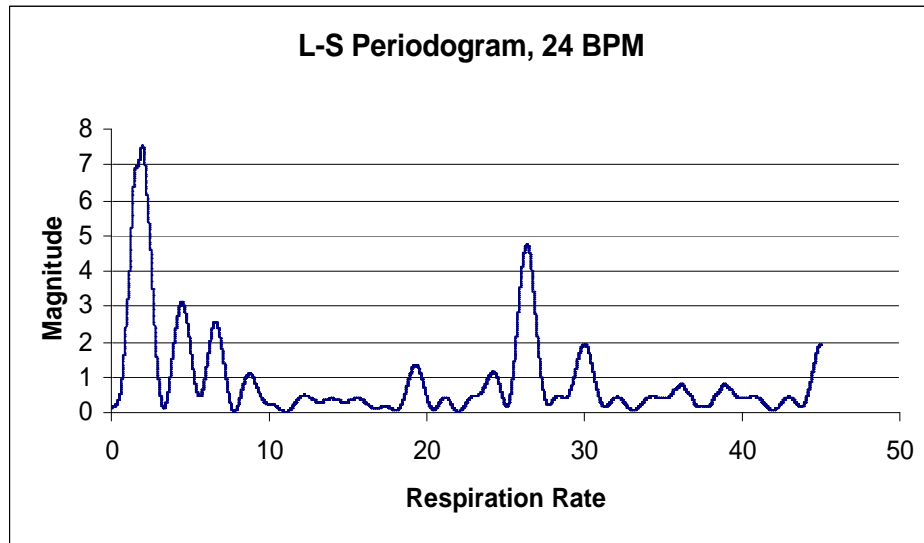
PSD, 12 BPM



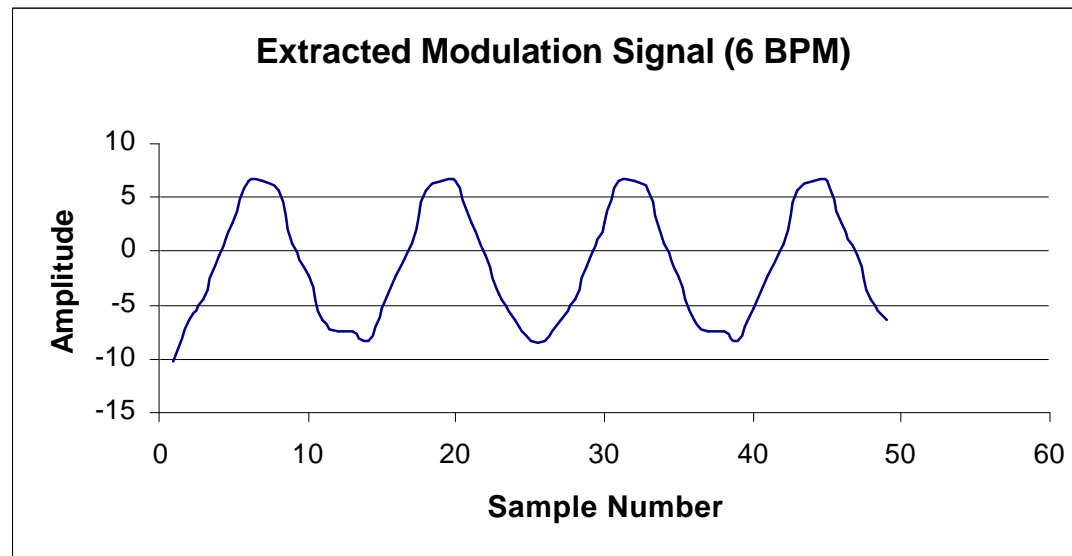
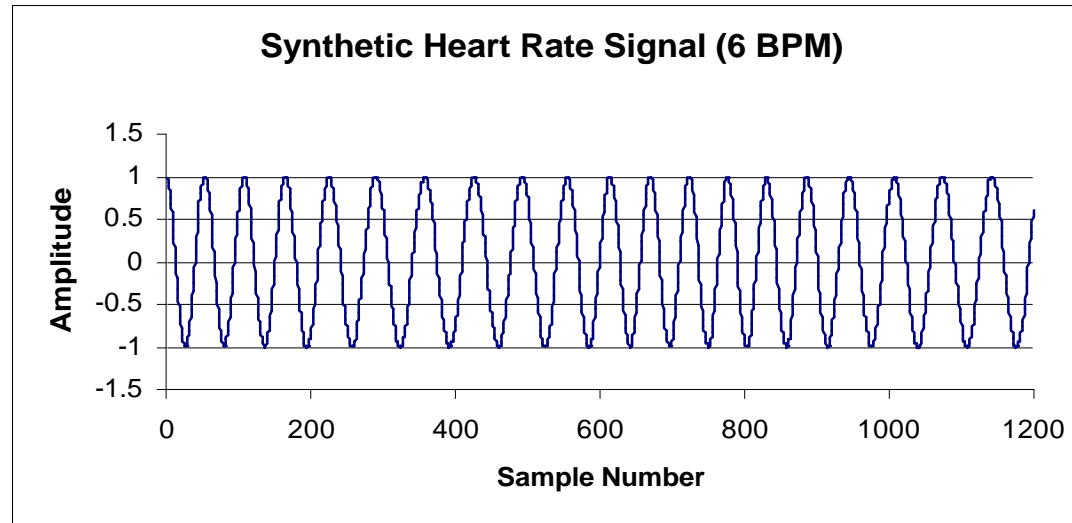
HR and Modulating Signal, 24 BPM, Experimental Data



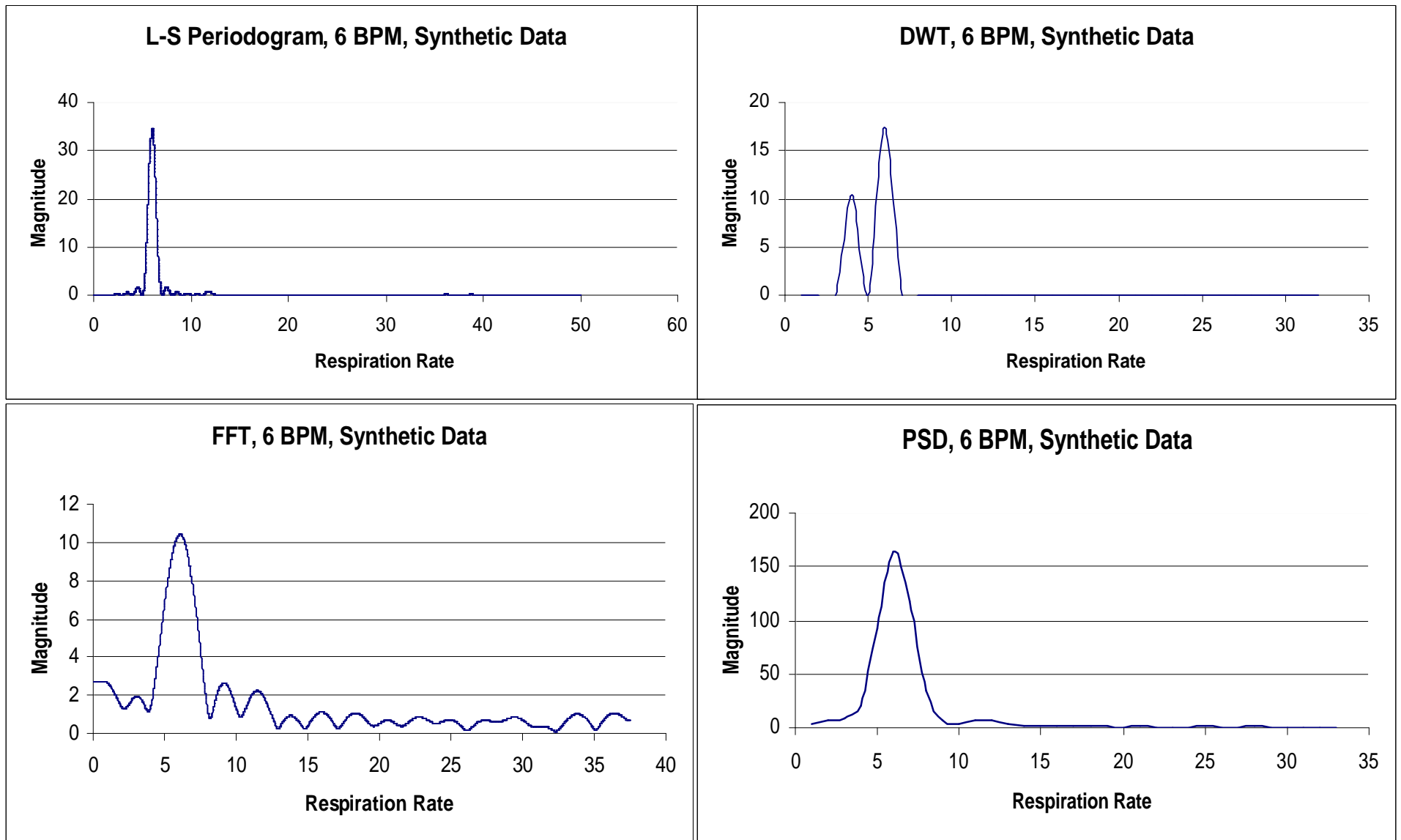
Spectrum Analysis, 24 BPM



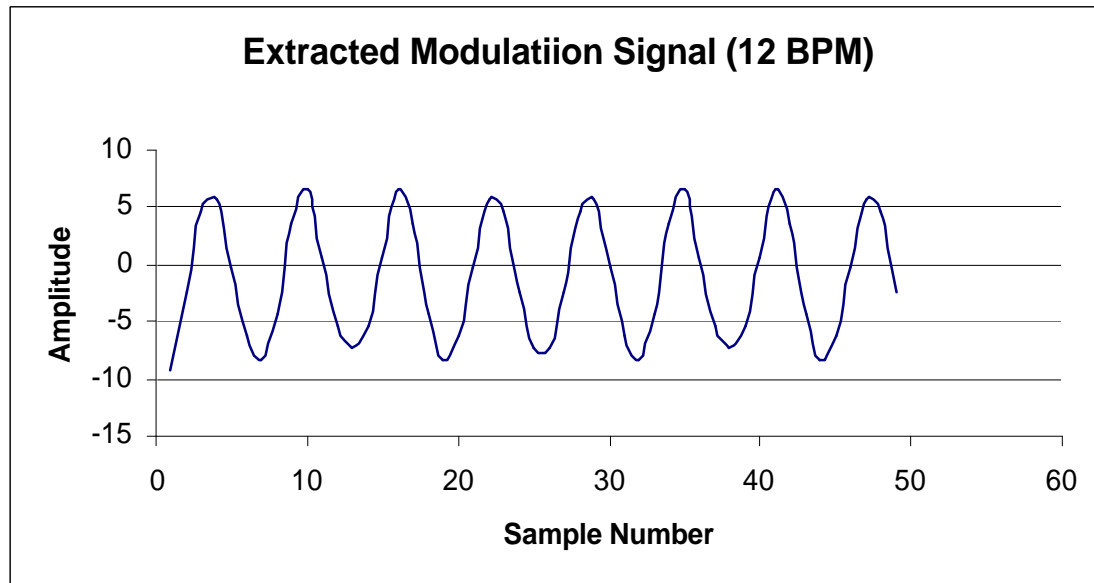
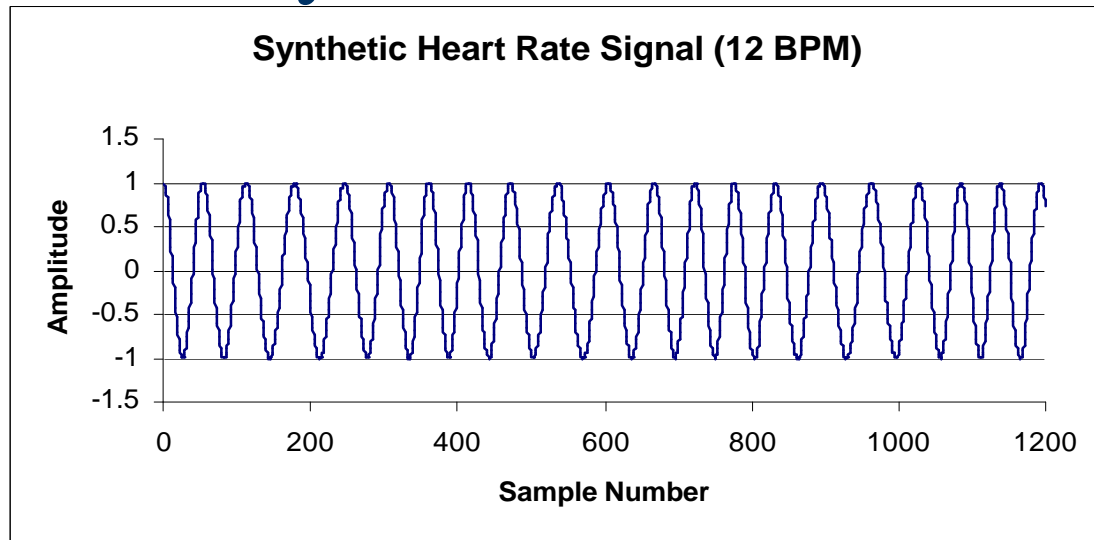
HR and Modulating Signal, 6 BPM, Synthetic Data



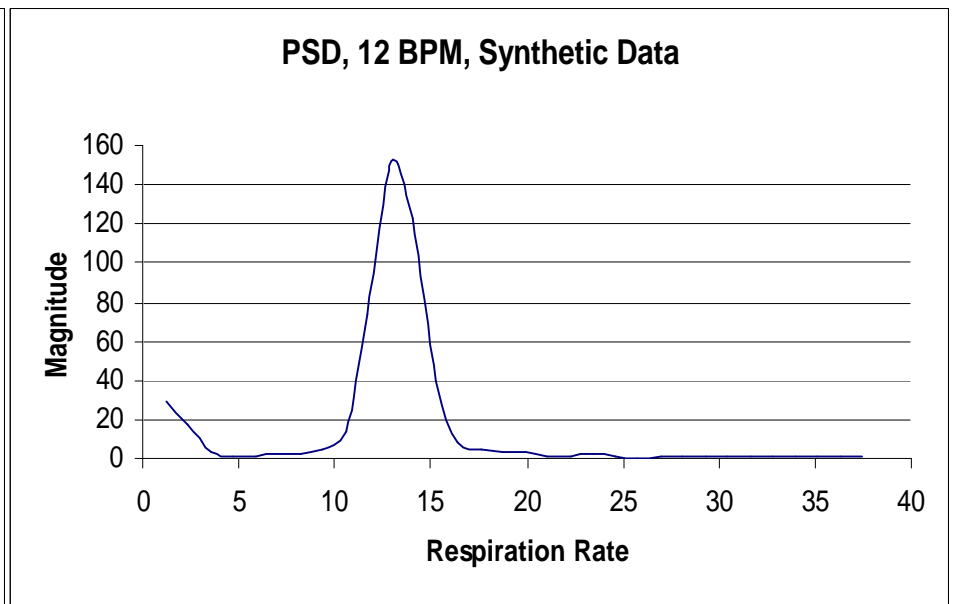
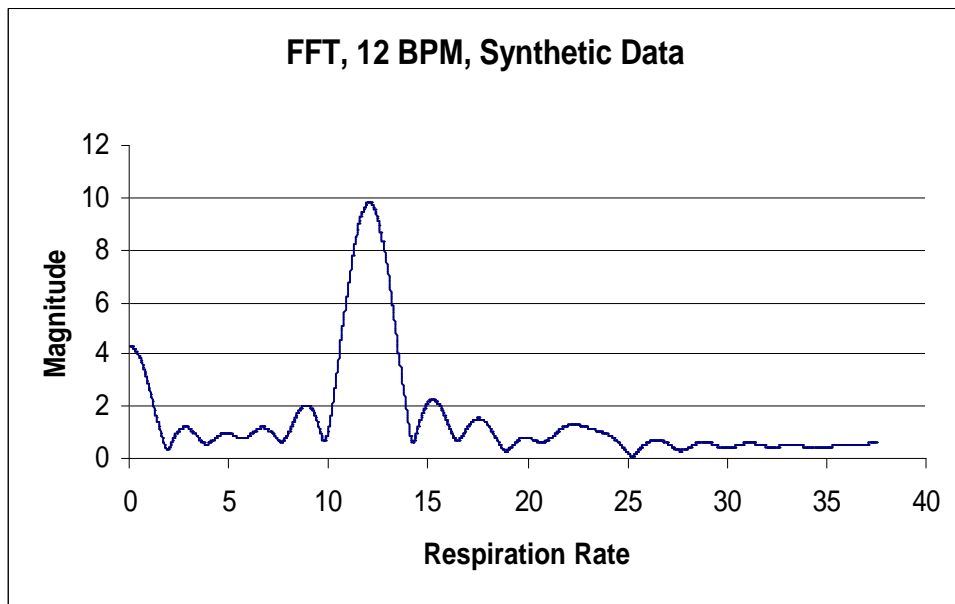
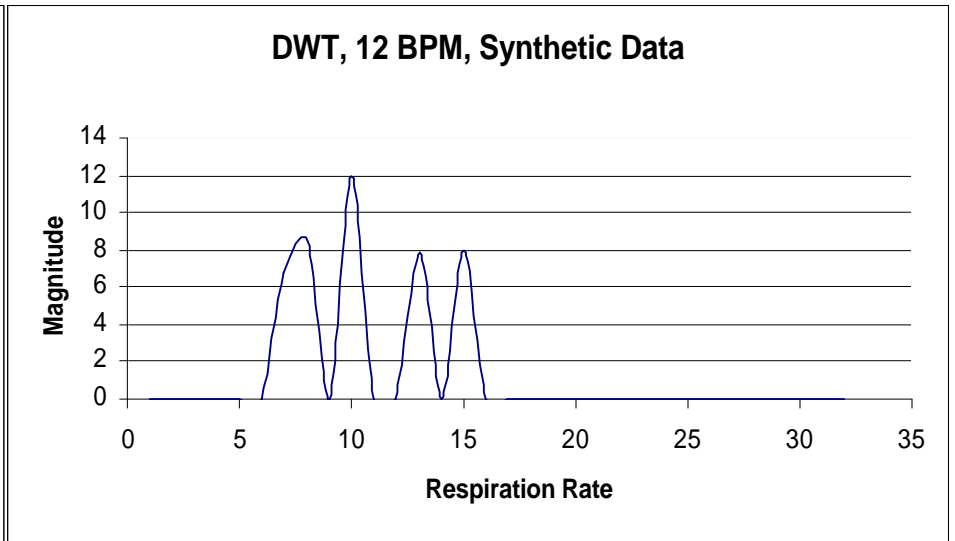
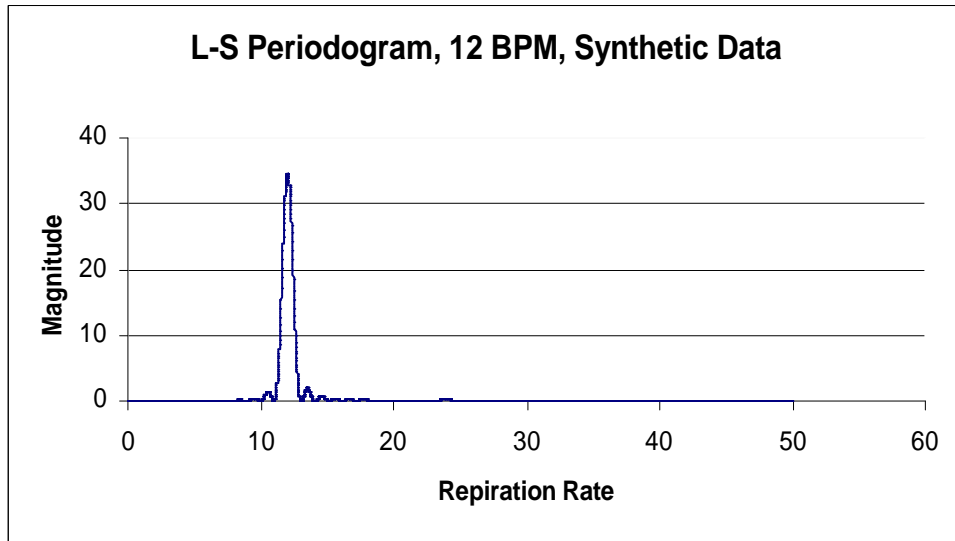
Spectrum Analysis, 6 BPM, Synthetic Data



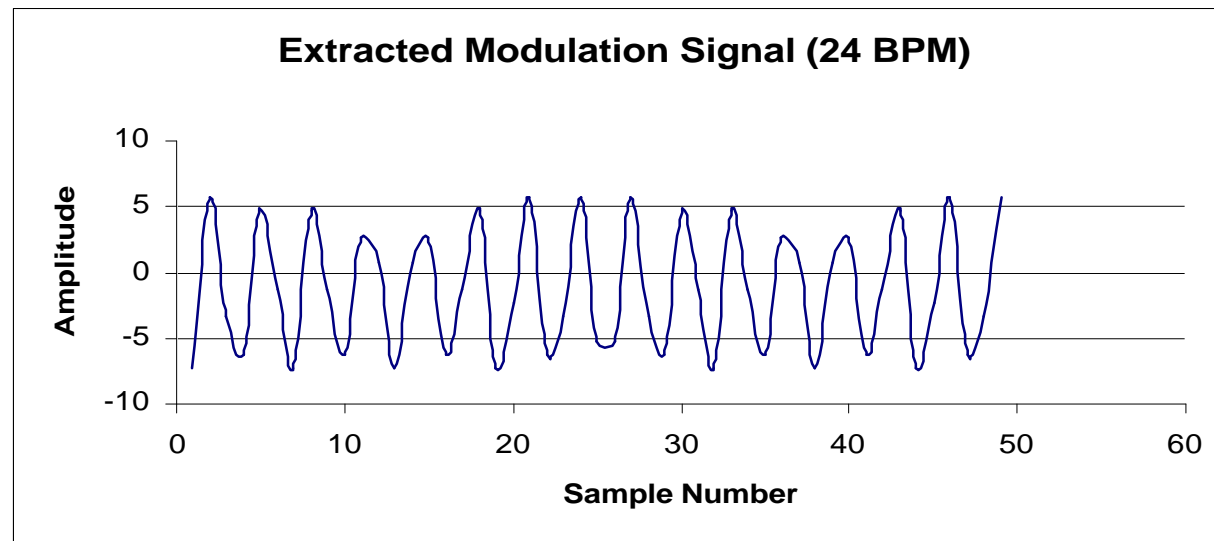
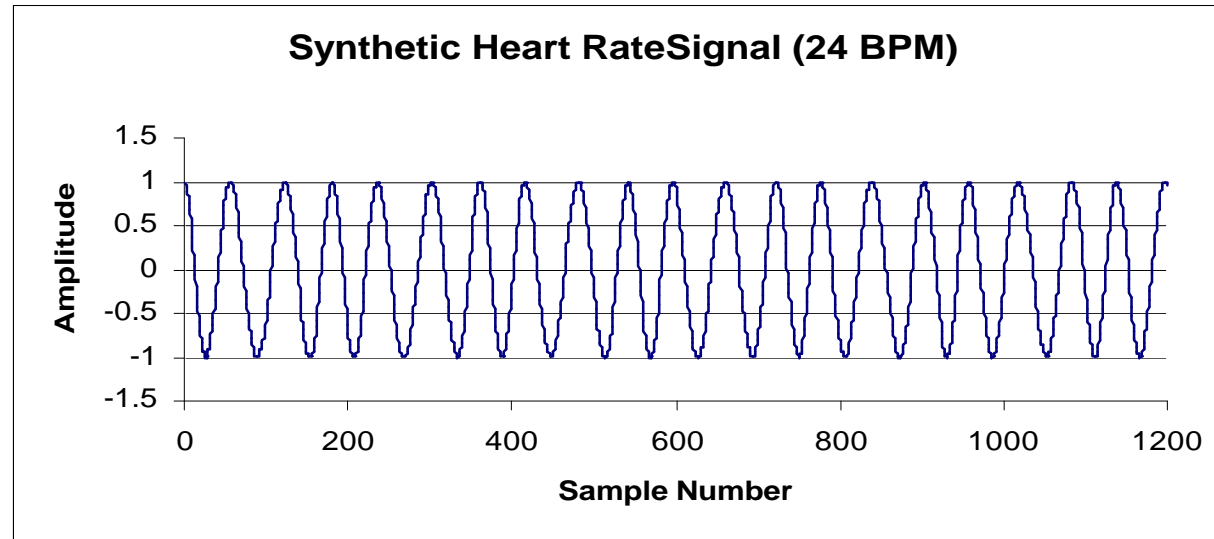
HR and Modulating Signal, 12 BPM, Synthetic Data



Spectrum Analysis, 12 BPM, Synthetic Data

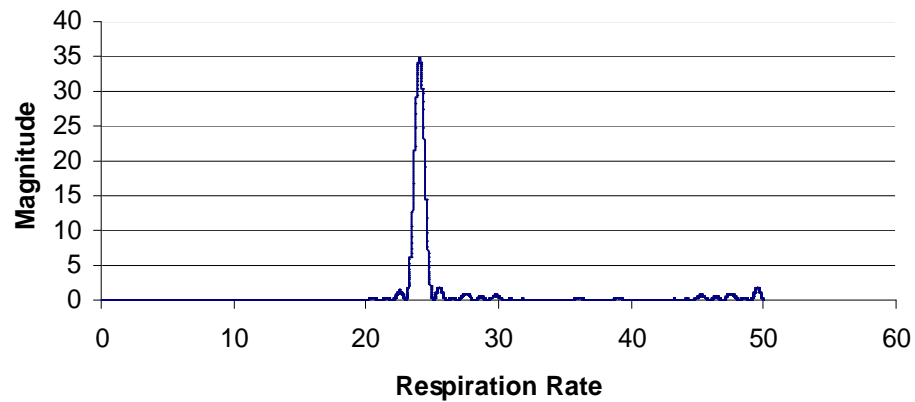


HR and Modulating Signal, 24 BPM, Synthetic Data

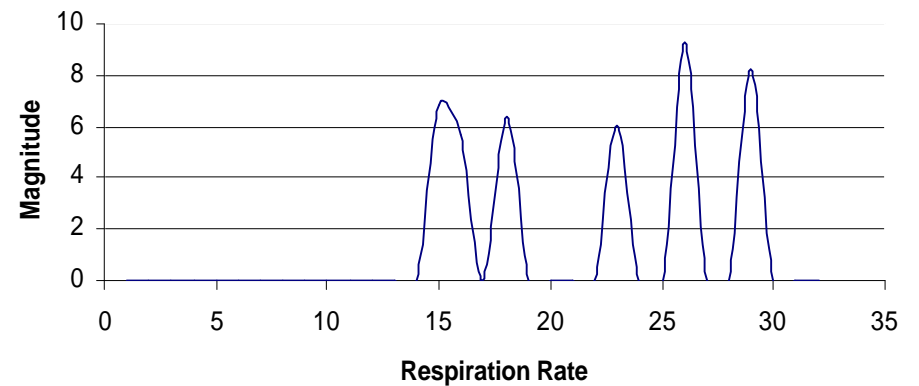


Spectrum Analysis, 24 BPM, Synthetic Data

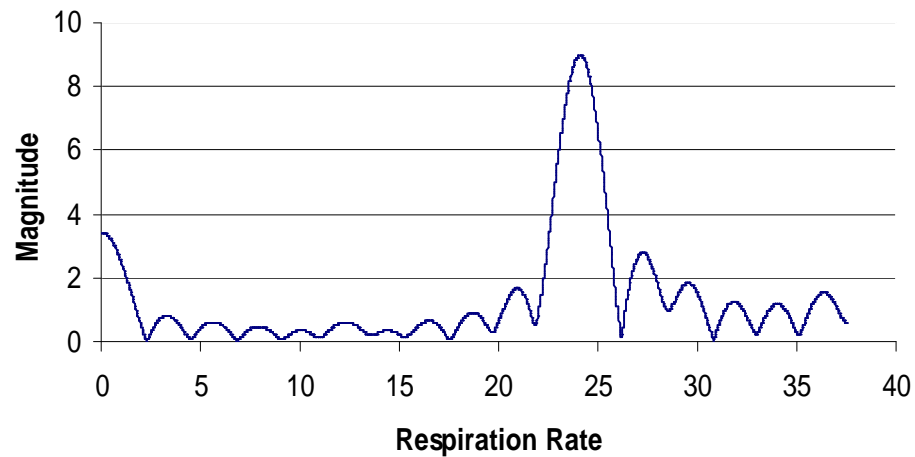
L-S Periodogram, 24 BPM, Synthetic Data



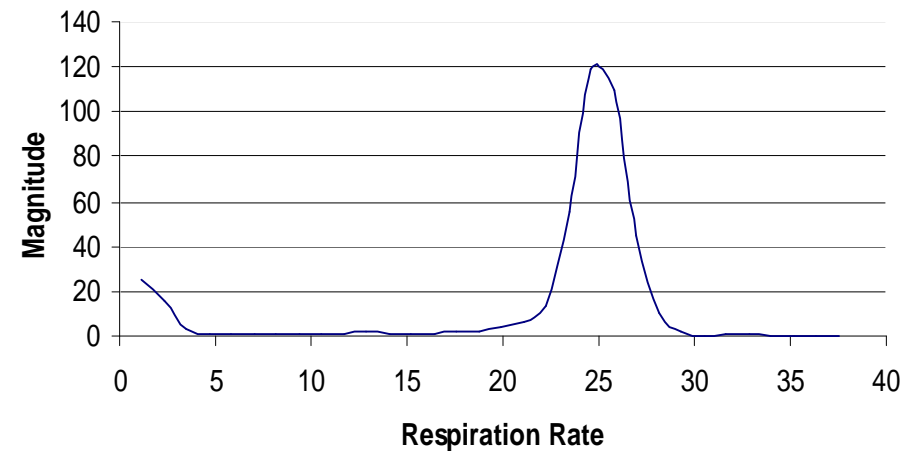
DWT, 24 BPM, Synthetic Data



FFT, 24 BPM, Synthetic Data



PSD, 24 BPM, Synthetic Data





Conclusion

- Frequency-modulation (FM) communication model successfully extracts respiration rate from HR
- Good performance with noisy data and moderately short (30 seconds) data lengths.
- Lomb-Scargle periodogram provided an efficient and technically correct method of spectrum analysis for non-uniformly sampled data.



Acknowledgements

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