ECG Signal Conditioning by Morphological Filtering

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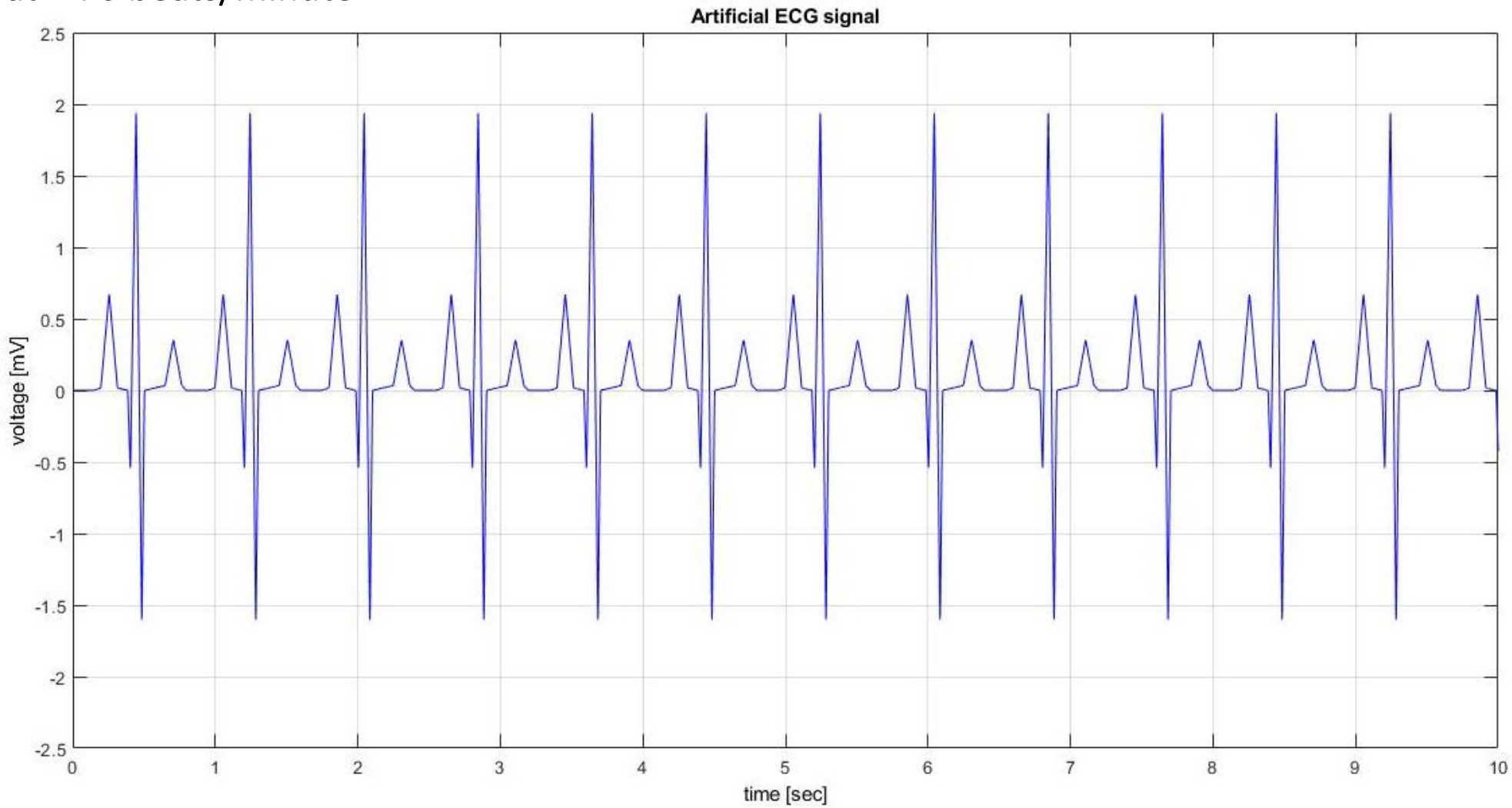
Practical Steps

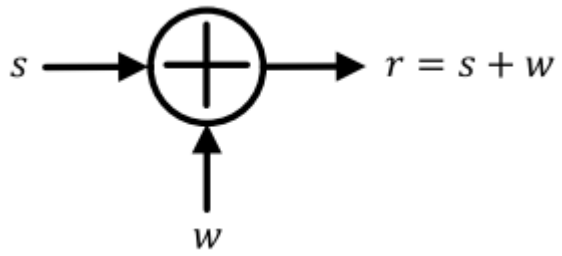
1. Synthesis an ECG signal
2. Noise with known characteristics
3. Baseline drift with known characteristics
4. Apply the filter multiple times
5. Decide on best Iteration

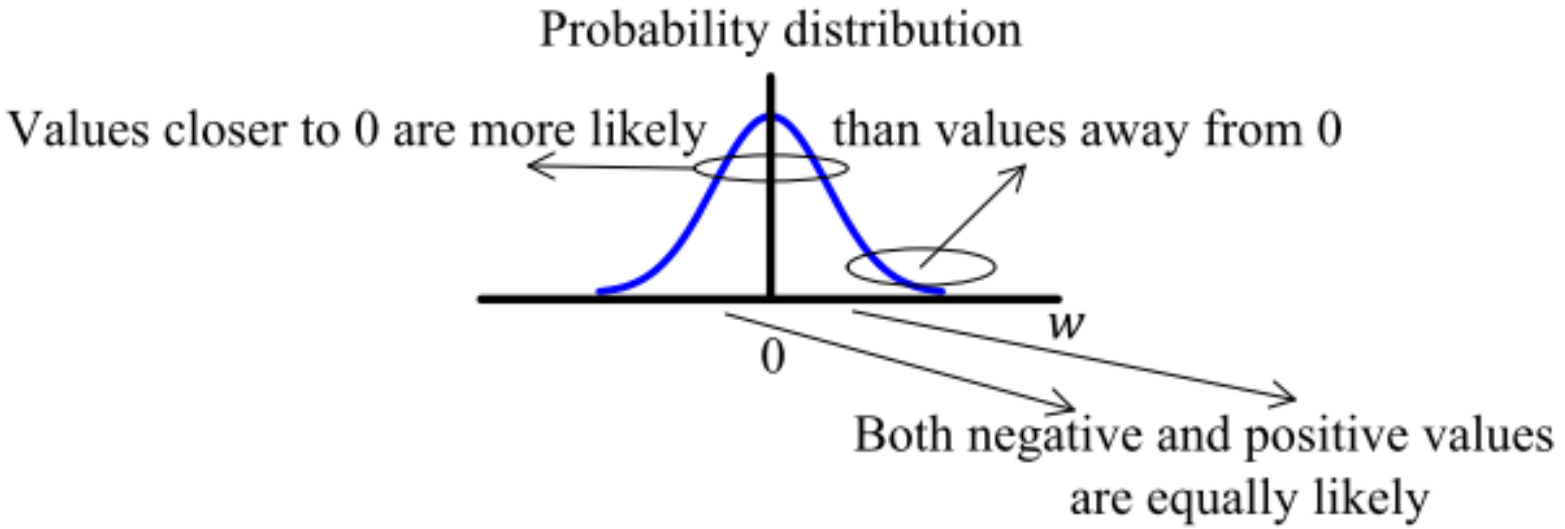
Peaks at 2.5 mV

Heart beat = 70 beats/minute

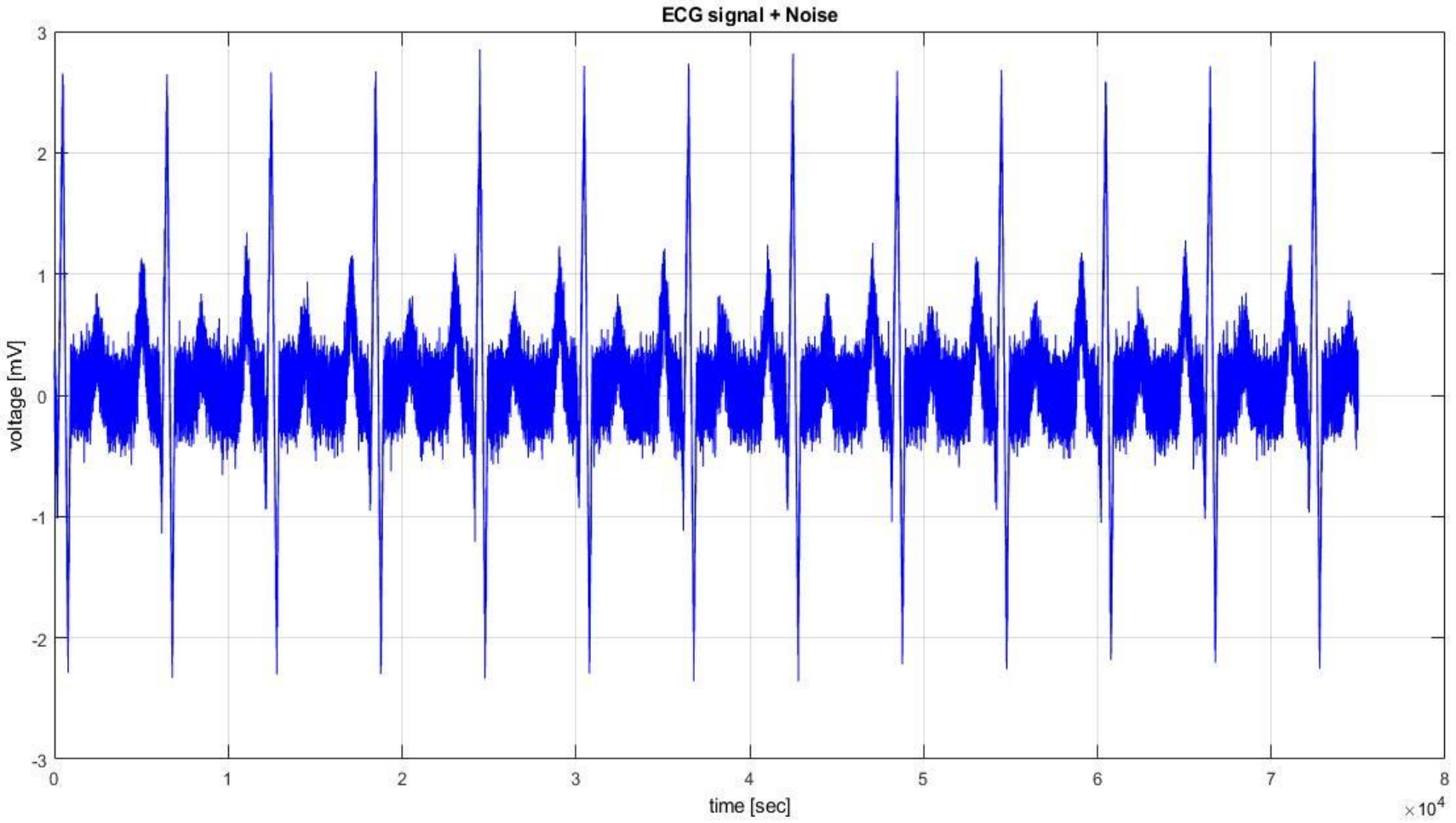


Additive White Gaussian Noise

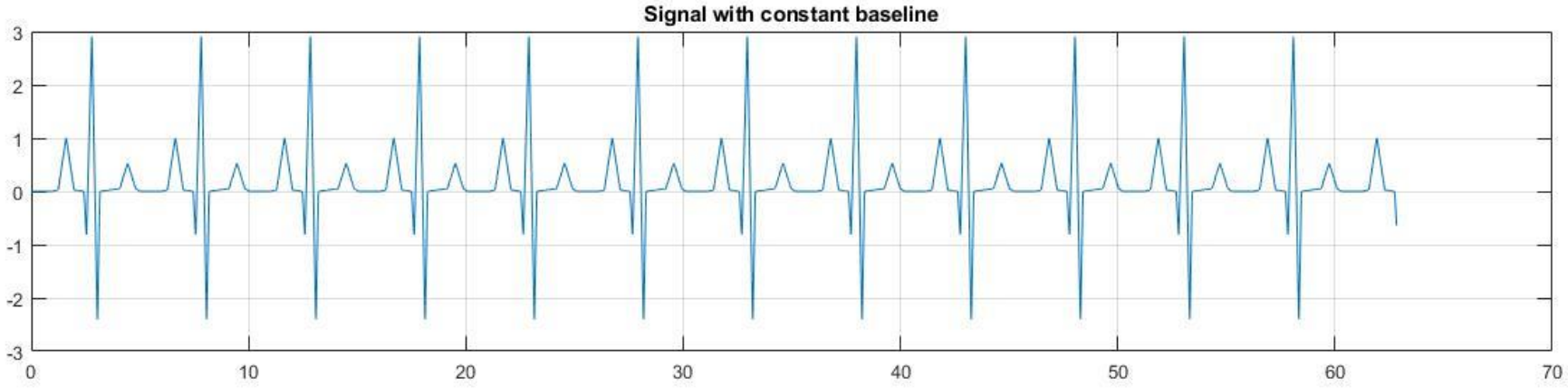


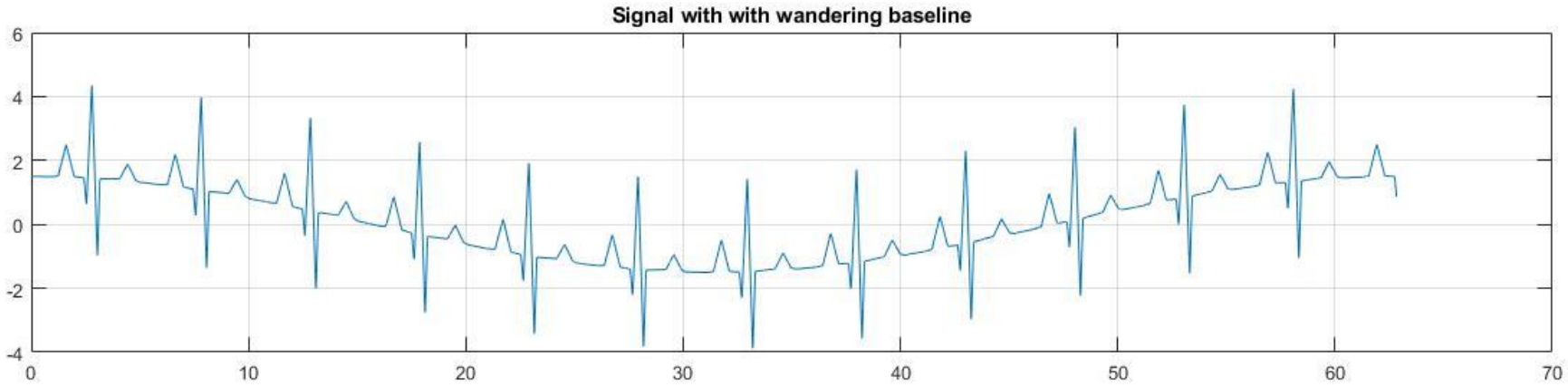


Noise + Raw ECG signal
SNR 10dB



Baseline drift

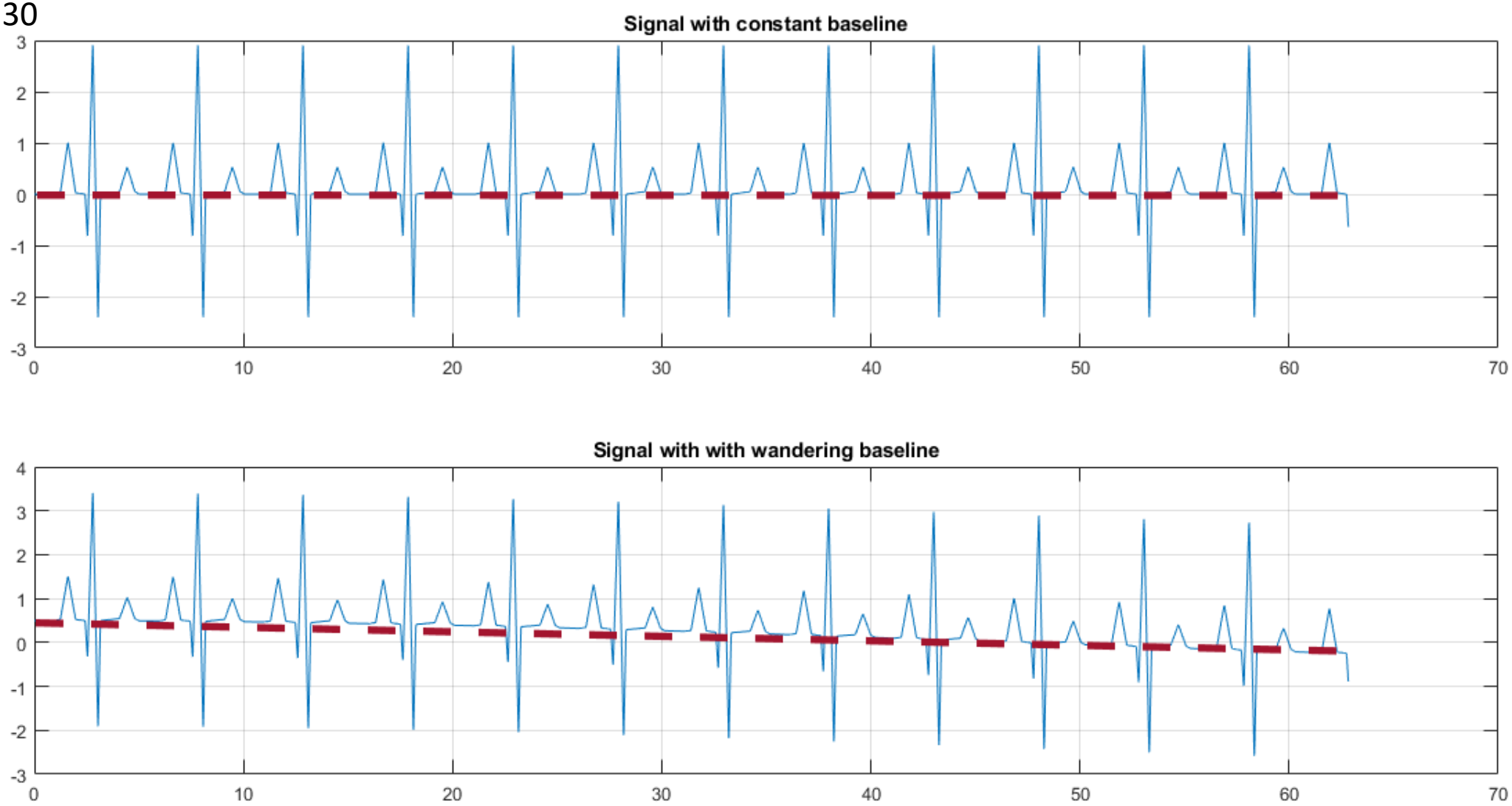




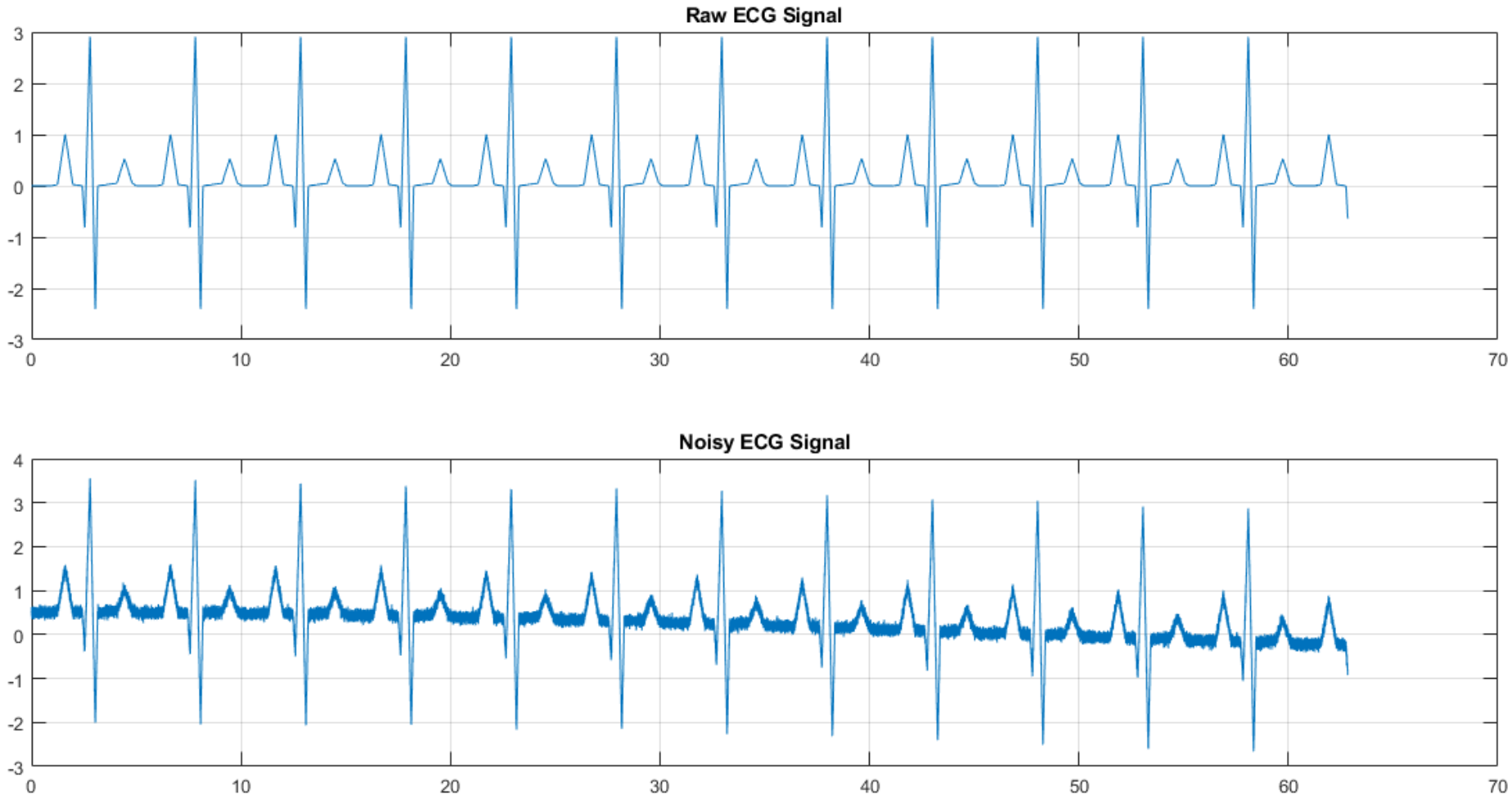
Amplitude of upward and downward drift = 1.5
Slope angle 10

Amplitude of upward and downward drift = 1.5

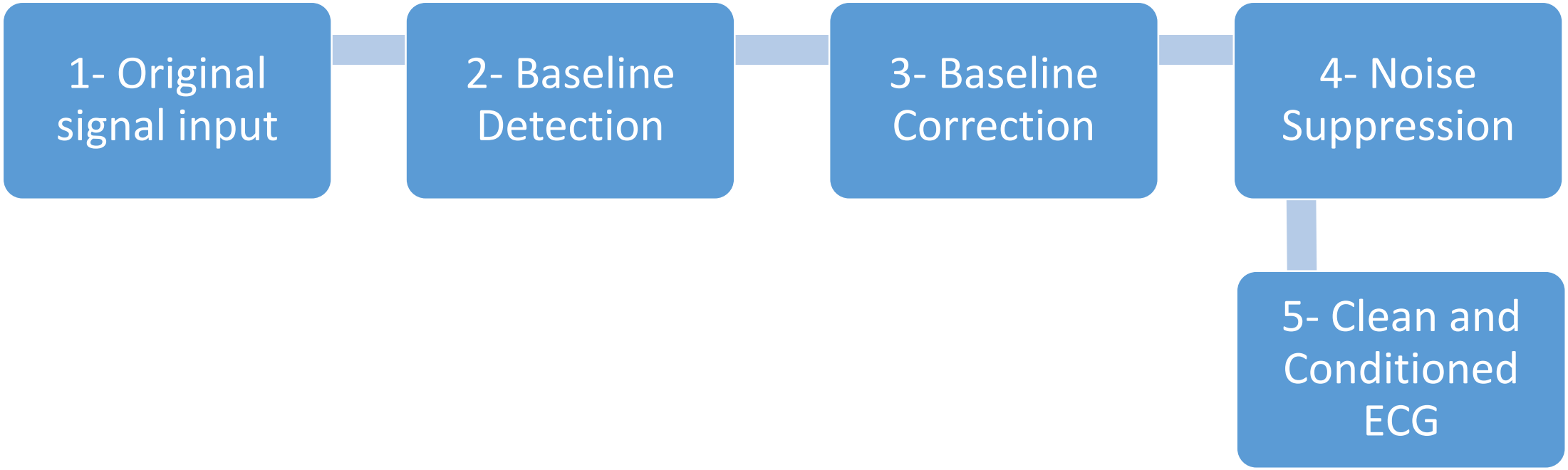
Slope angle = 30



Noise Contaminated ECG Signal



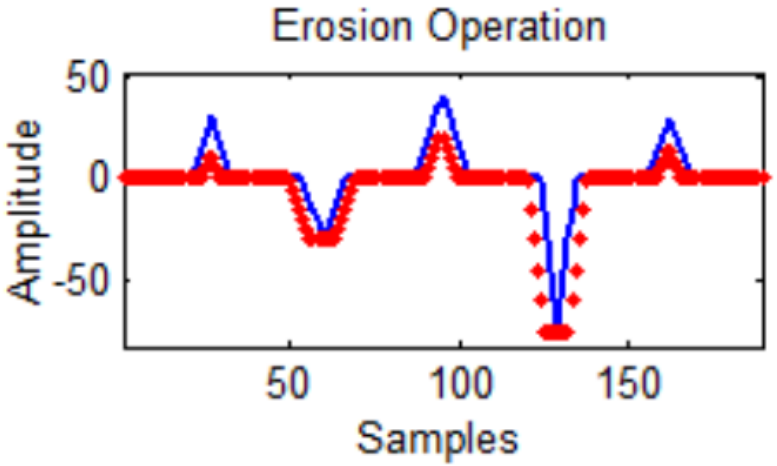
Methodology

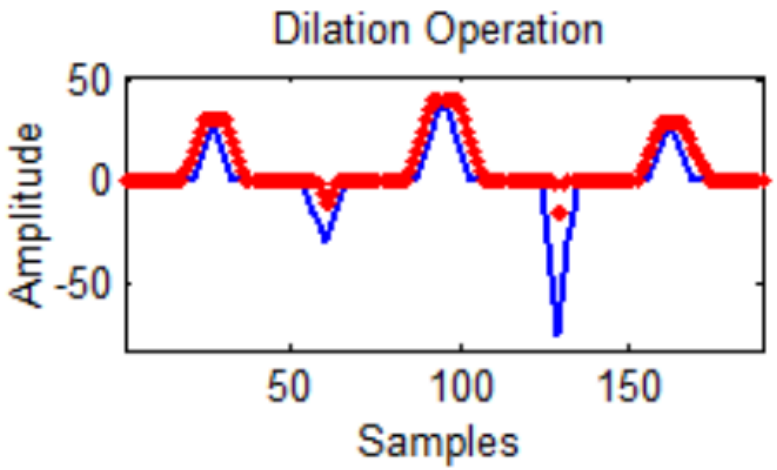


Mathematical Morphology Operators

1- Opening

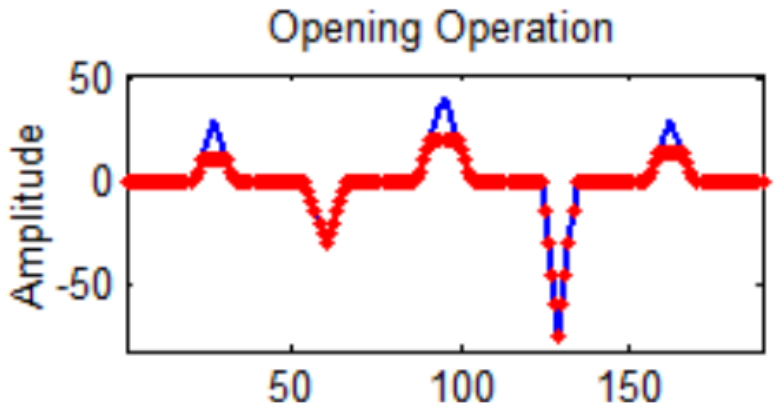
Erosion
Dilation

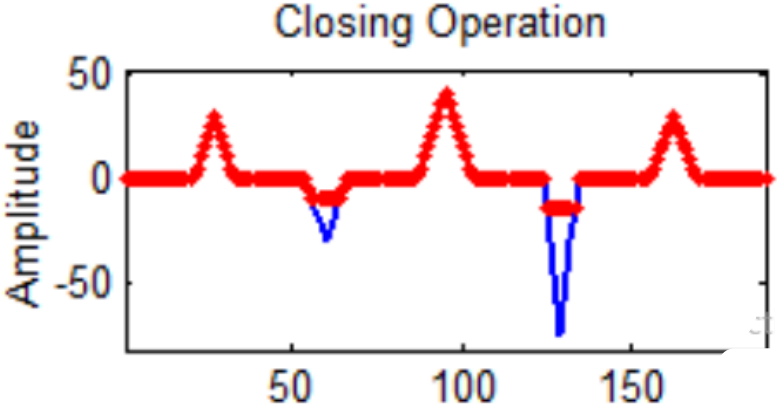




2- Closing

Dilation
Erosion





2- Baseline Detection

1- Opening

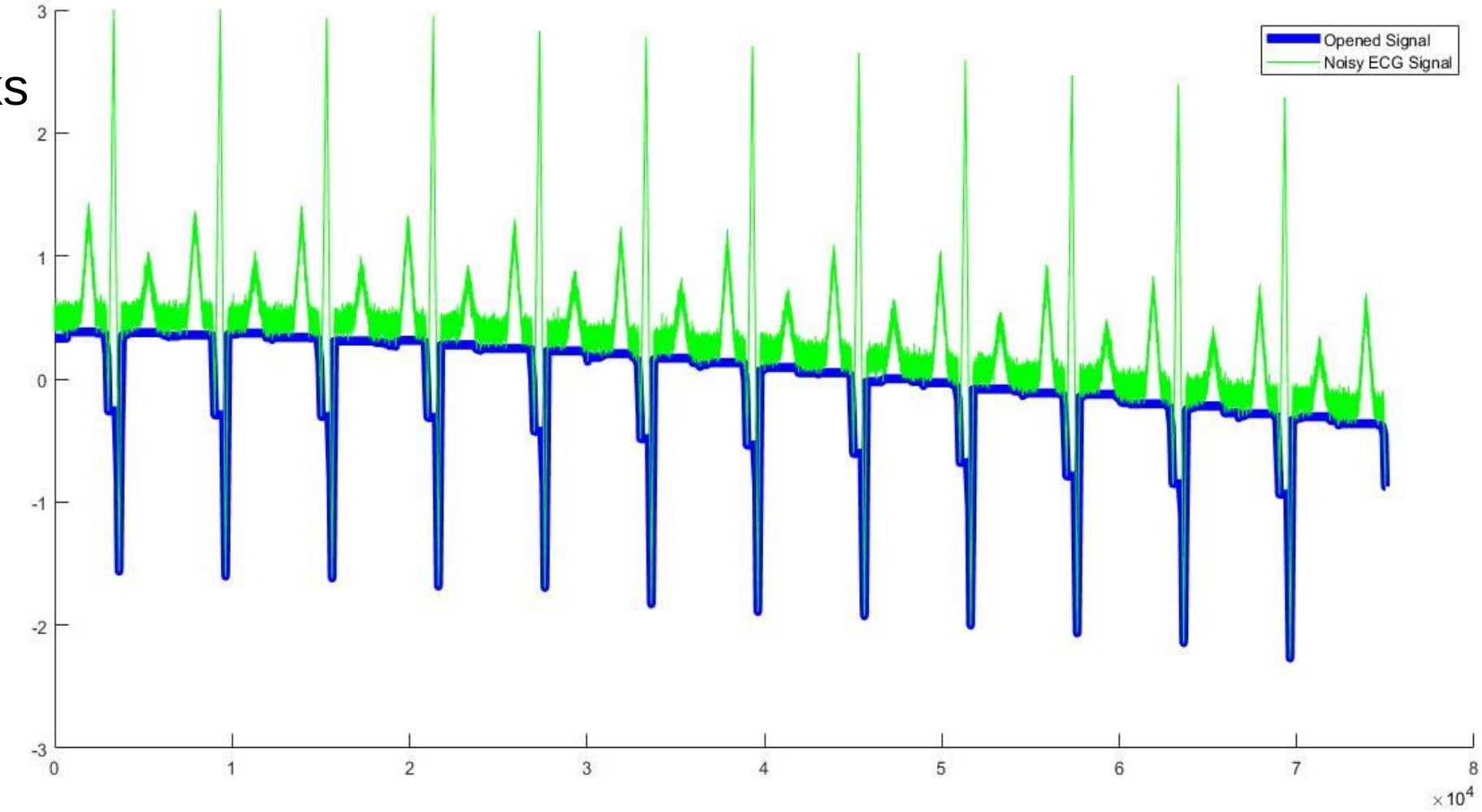
STEL length ≥ T . Fs (sampling frequency)

2- Closing

STEL length ≥ 1.5 . STEL opening

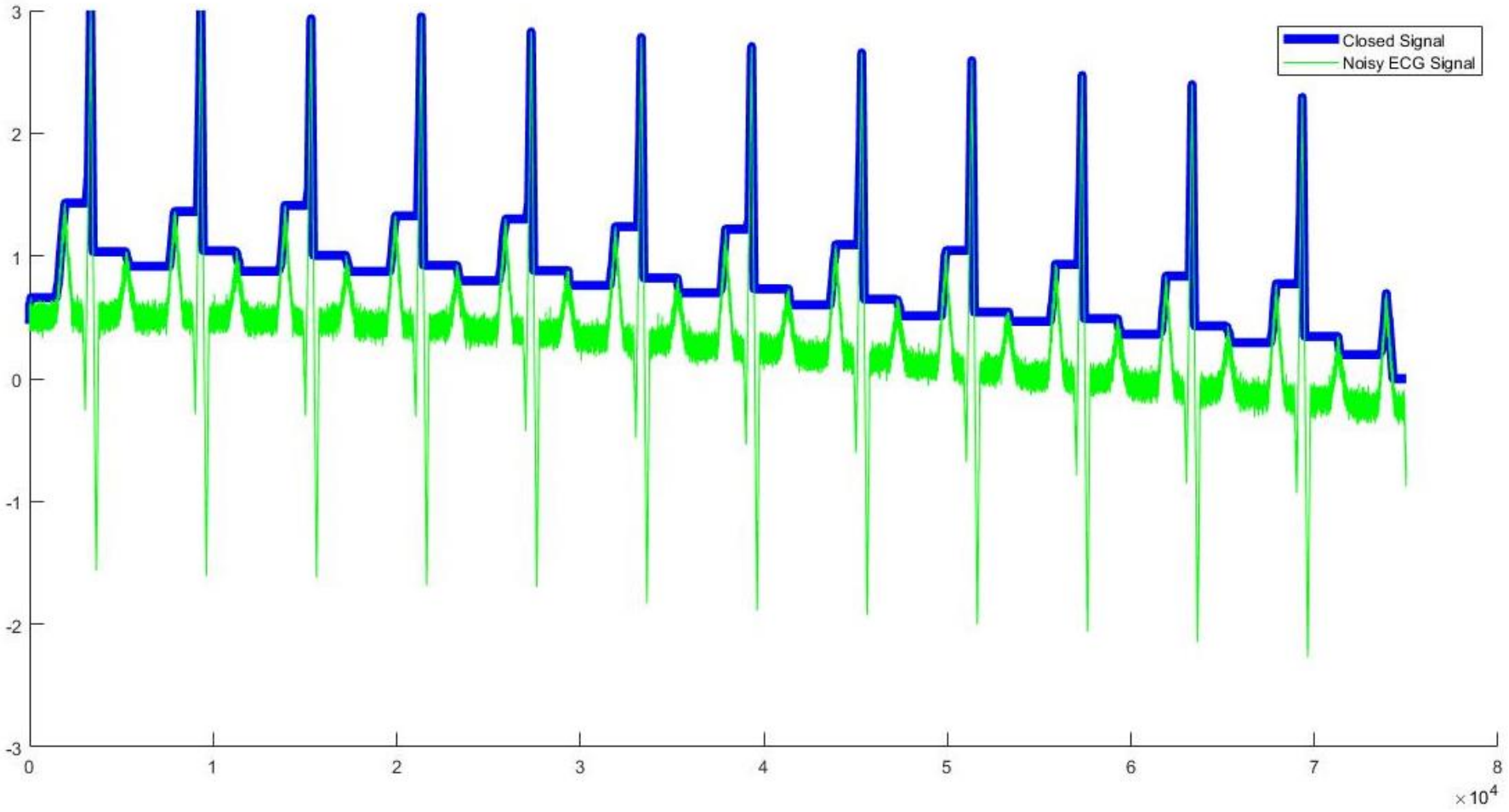
2- Baseline Detection (Opening)

- Remove the peaks

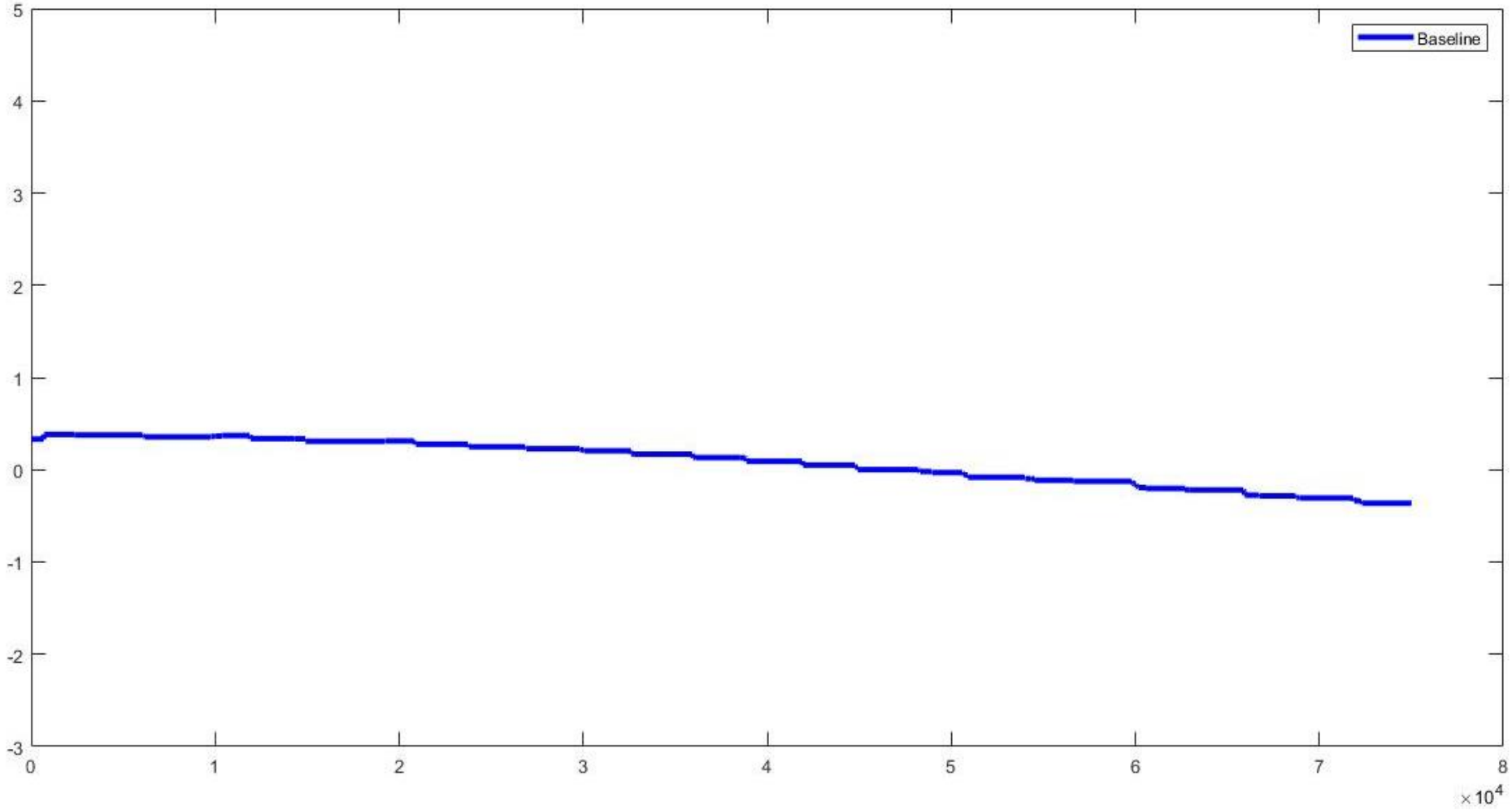


2- Baseline Detection (Closing)

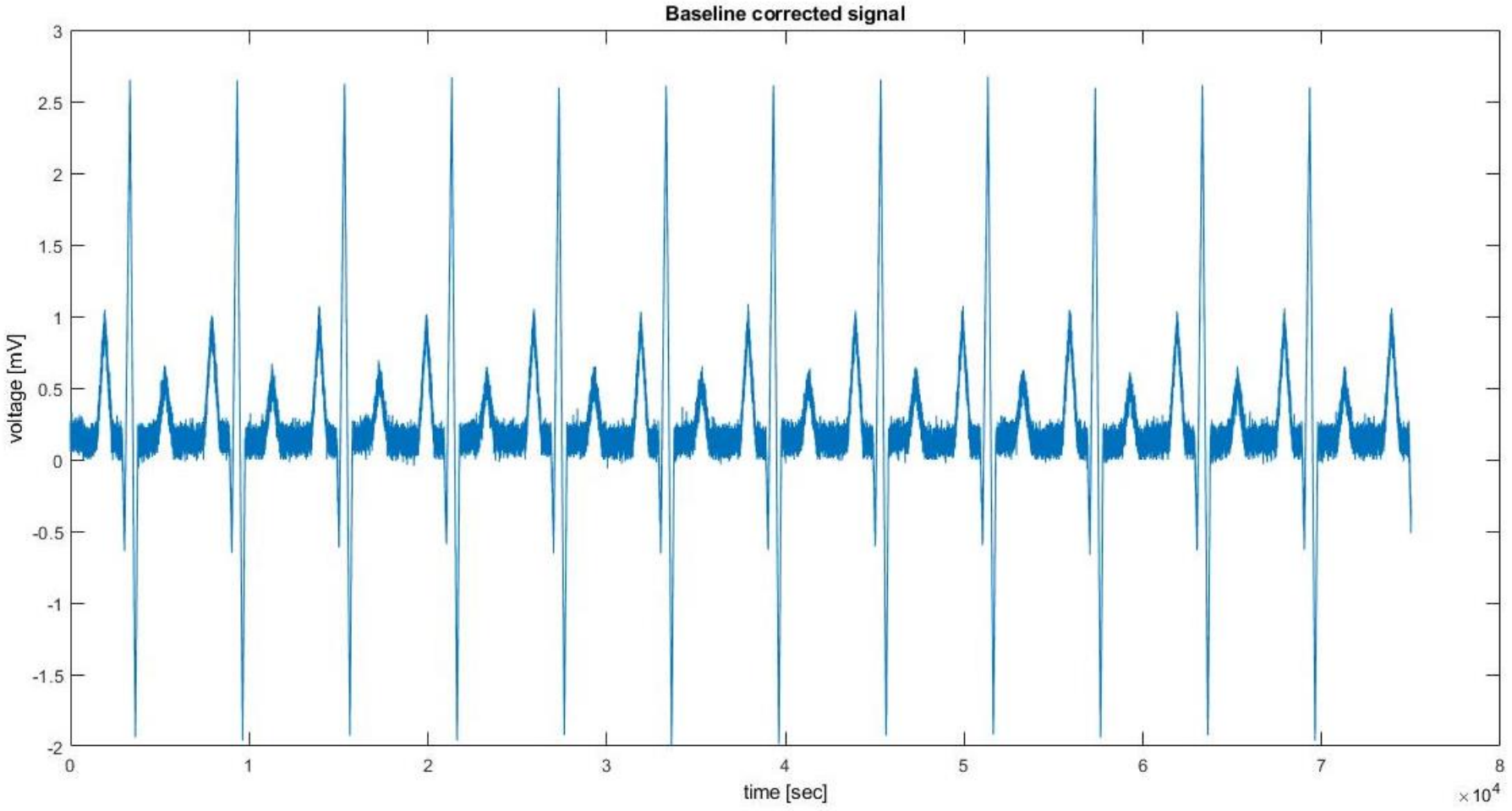
- Remove the pits



2- Baseline Detection

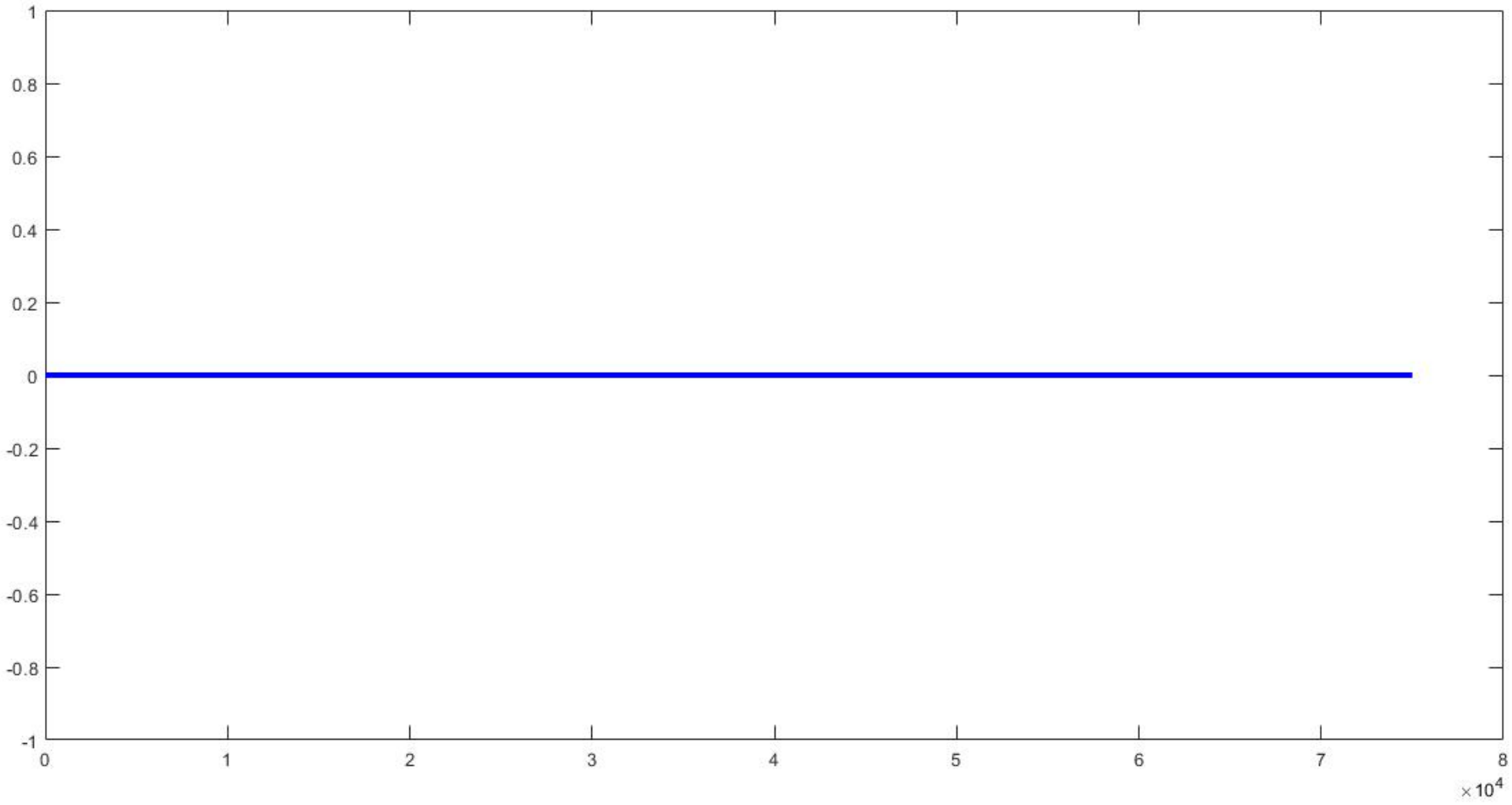


3- Baseline Correction



Subtracting the Result from the original signal.

3- Baseline Correction (Check)



Same process on result signal after baseline correction with the same Strel's to see whether the detected baseline is flat.

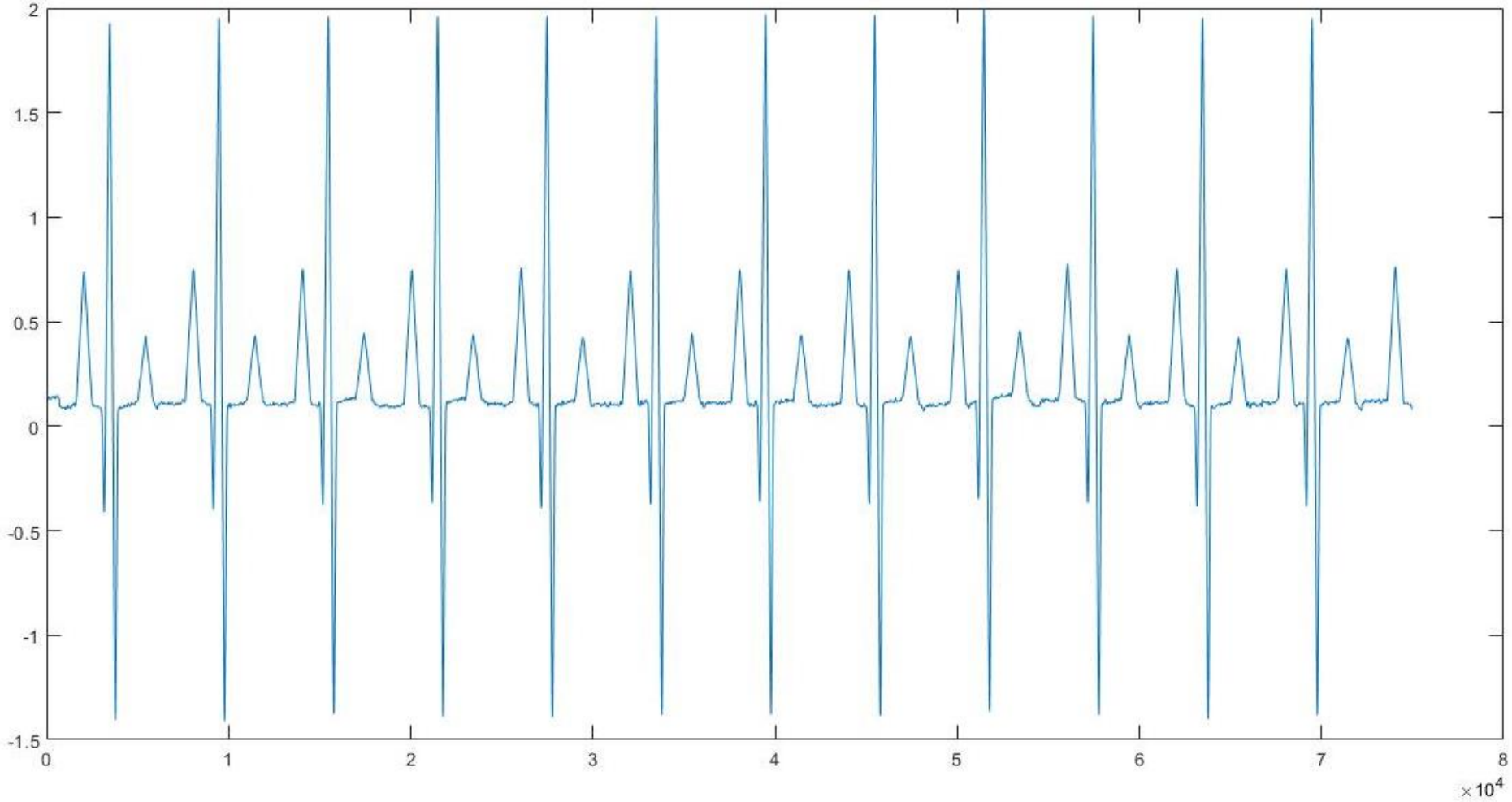
4- Noise Suppression

- Concurrently opening and closing the signal
- Compute the average of them
- $$f = \frac{1}{2}(f_{\text{bc}} \bullet B_{\text{pair}} + f_{\text{bc}} \circ B_{\text{pair}})$$

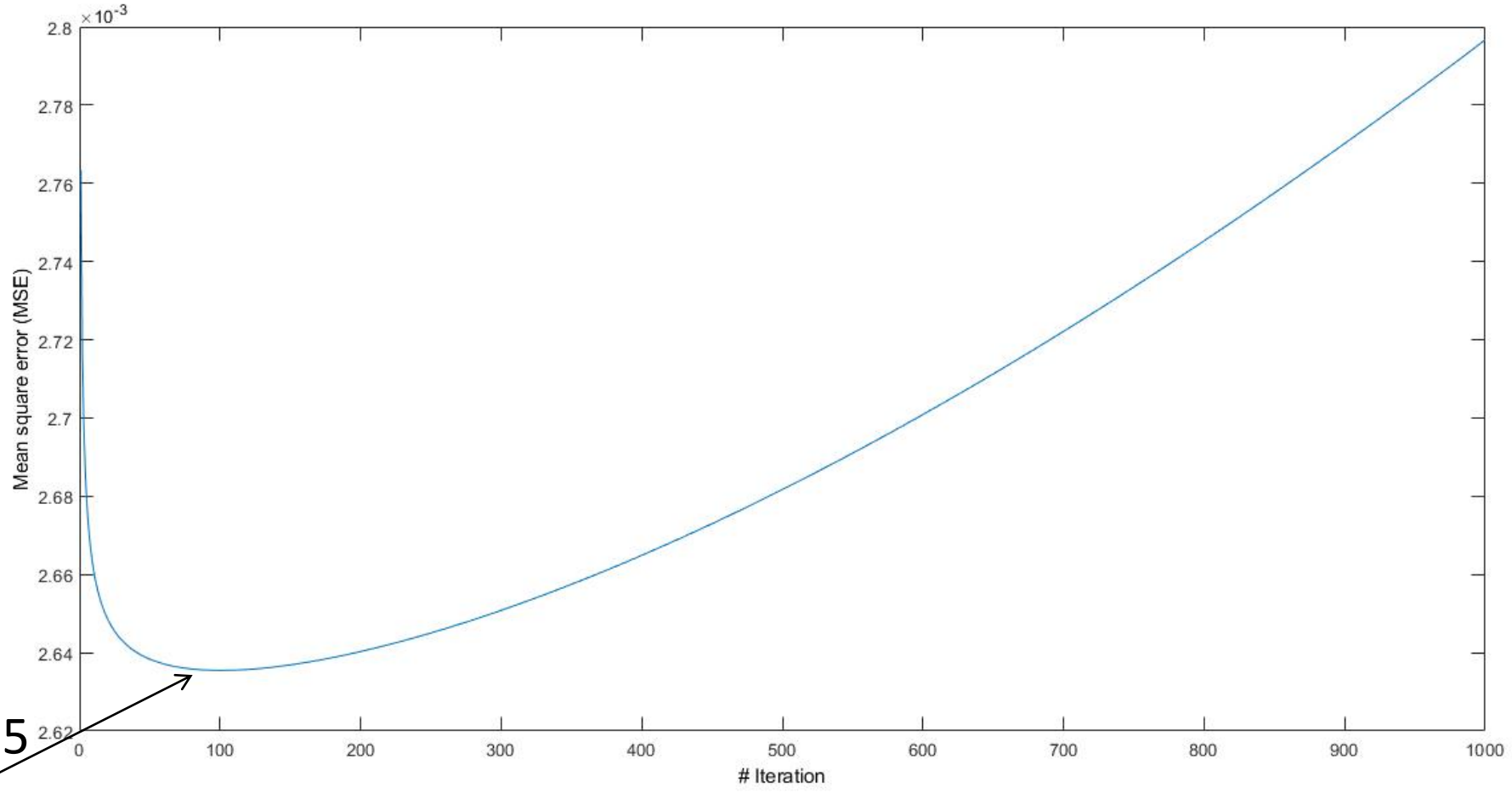
$$= \frac{1}{2}(f_{\text{bc}} \oplus B_1 \ominus B_2 + f_{\text{bc}} \ominus B_1 \oplus B_2),$$

F = Resultant Signal
Fbc = Signal after baseline correction
B = Structuring Elements

4- Noise Suppression(Result)

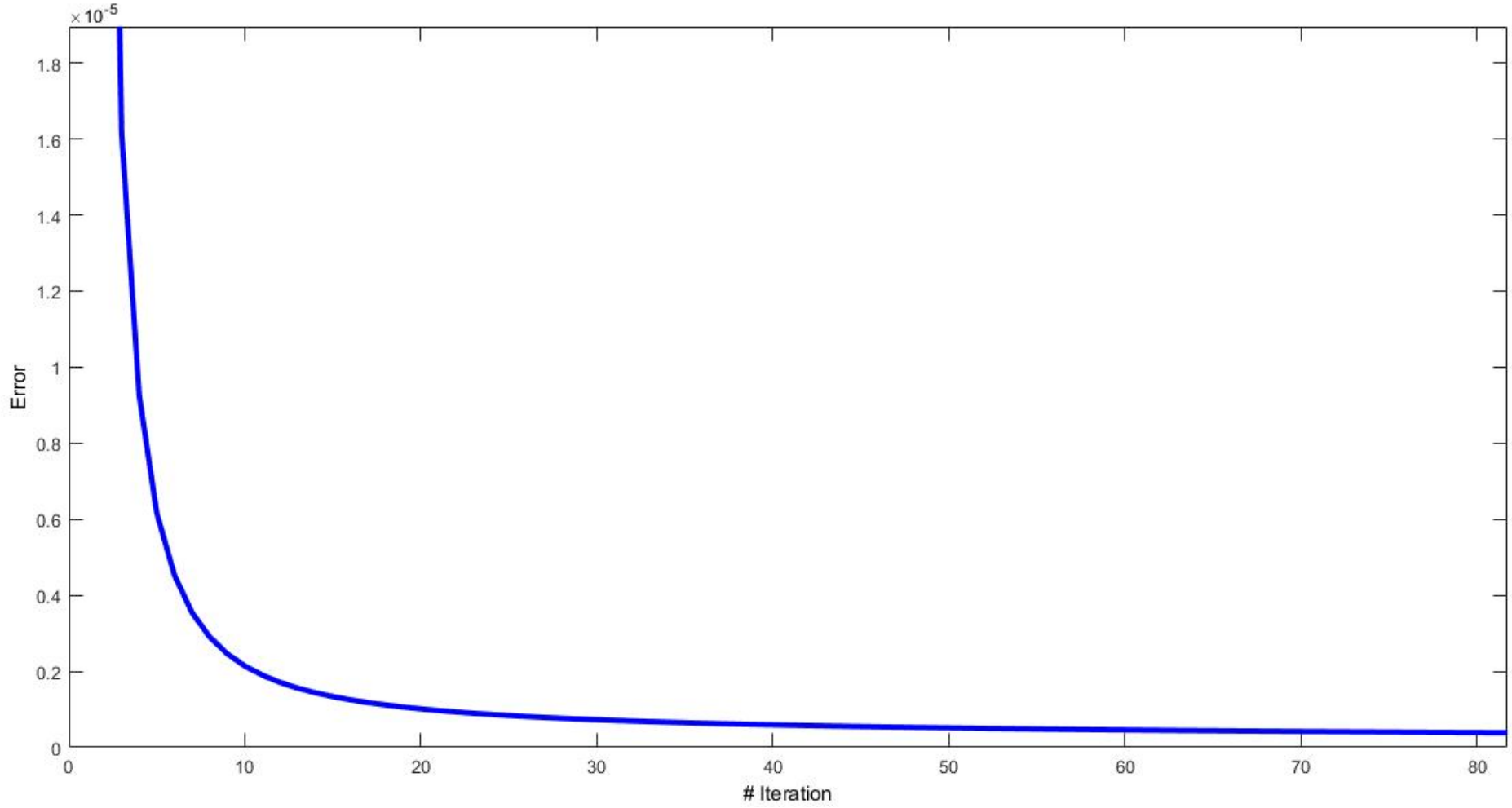


5- Mean Square Error (MSE)



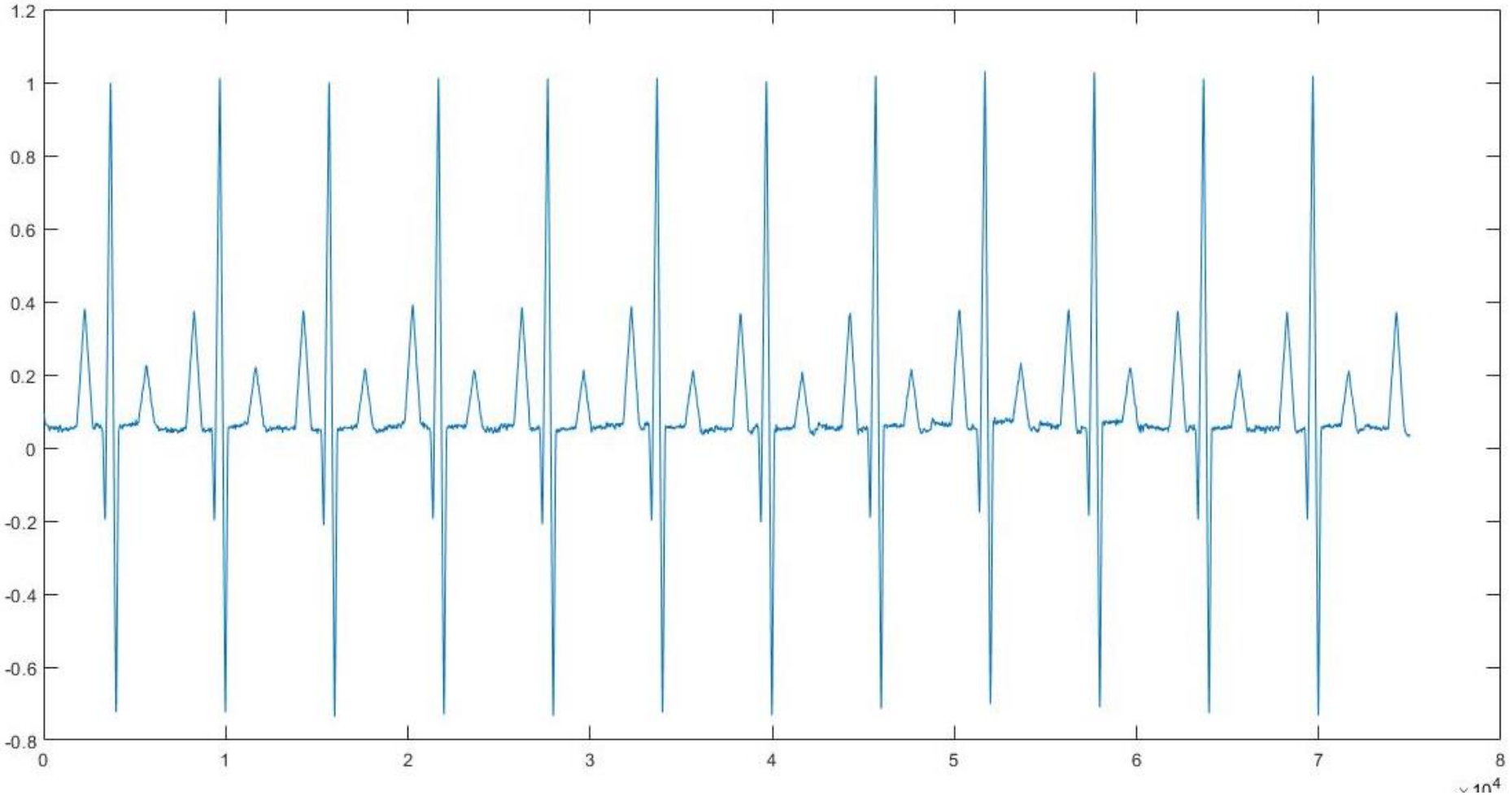
Iteration = 95

5- Difference Error



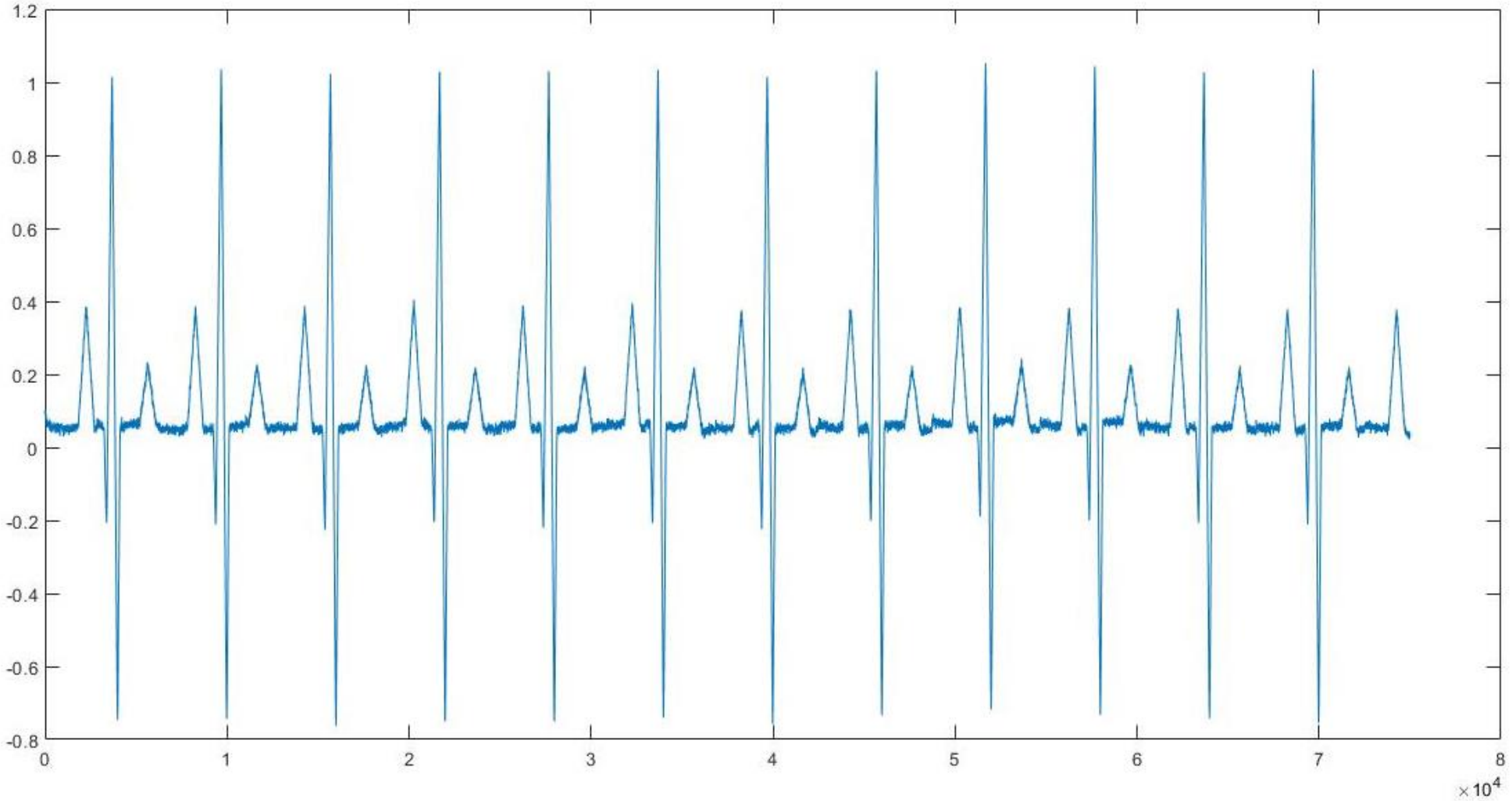
5- Comparison

95 Iteration



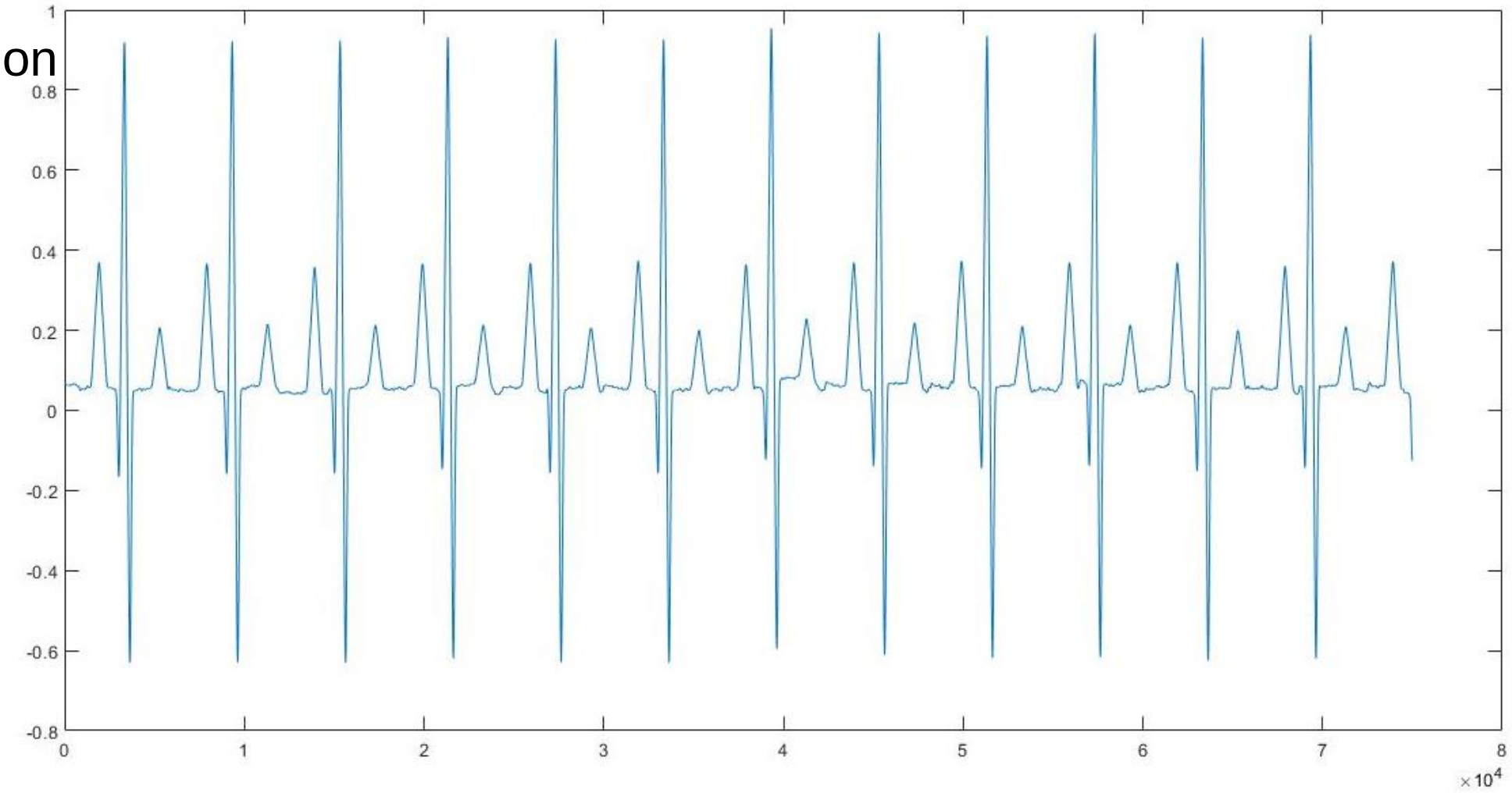
5- Comparison

10 Iteration



5- Comparison

1000 Iteration



Thank you for listening

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