

# Processing Multielectrode EEG Signals

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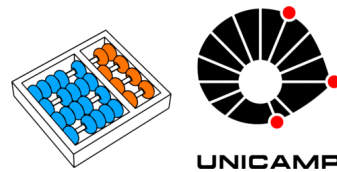
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# Processing Multielectrode EEG Signals

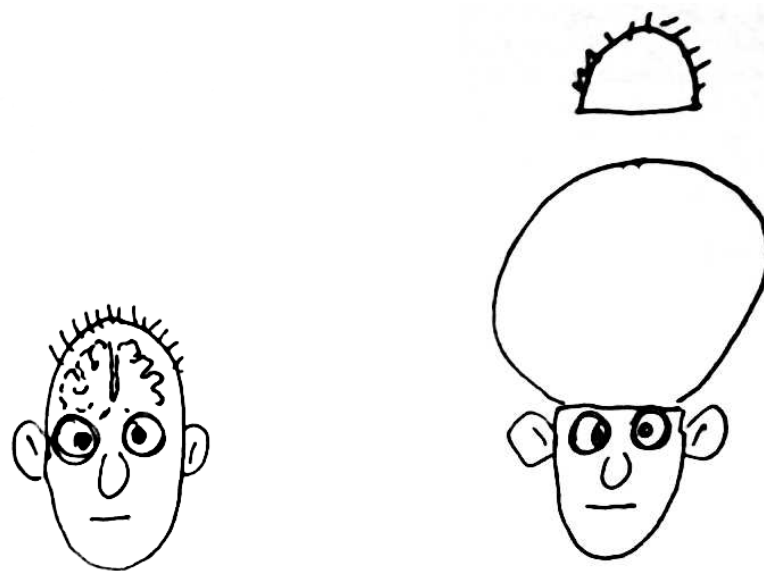
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## The human cortex (“grey matter”)

- About 3 mm thick.
- About 0.2 m<sup>2</sup> area unfolded.
- About 10<sup>11</sup> neurons.



## Columnar organization:

- About  $10^5$  columns.
- About  $10^6$  neurons per column.
- Several layers of neurons with distinct morphology.
- Axons are generally directed inwards.
- Neurons in one column tend to fire simultaneously.
- “White matter” is myelinated axons connecting columns.

Single neuron firings cannot be detected by EEG:

- Neural pulses have high voltages (100 mV) but low energy.
- Multipole potentials decay rapidly ( $1/r^3$  or faster).
- Too many neurons firing at the same time.
- Neuronal pulses last  $\sim 1$  ms.
- Neuron can fire at nearly 200 Hz.

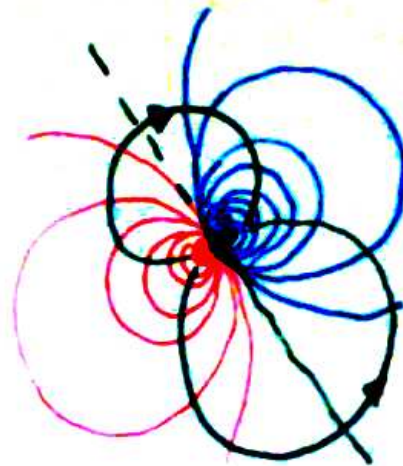
Column activity can almost be detected:

- Each neuron firing transports a bit of charge down the axon.
- Thousands to millions of neurons in a column fire together.
- Neurons are generally oriented with axon inwards.

Result: significant *dipole* potential field.

## Dipole current source:

- Return current distributed through medium.
- Bi-lobe potential distribution.
- Potential decays like  $1/r^2$ .



Pattern expected on scalp for single dipole source:

- Spot-and-halo pattern for normal dipole.
- Bipolar pattern for parallel dipole.
- Potential decays like  $1/r^2$  away from maximum.
- Amplitude decays with  $1/d^2$ .

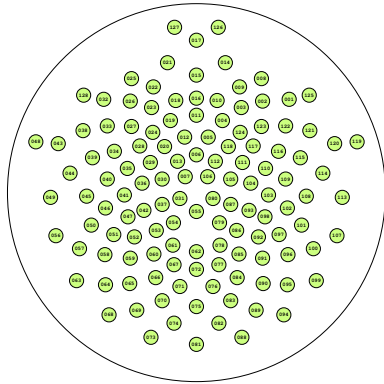


A single column is still too weak to be detected

- Detectable only if many adjacent columns fire together.
- There are  $10^5$  columns but only  $10^2$  measurements.
- At best we can detect activity in  $10^2$  regions.
- Unblurring (Laplacian filtering).

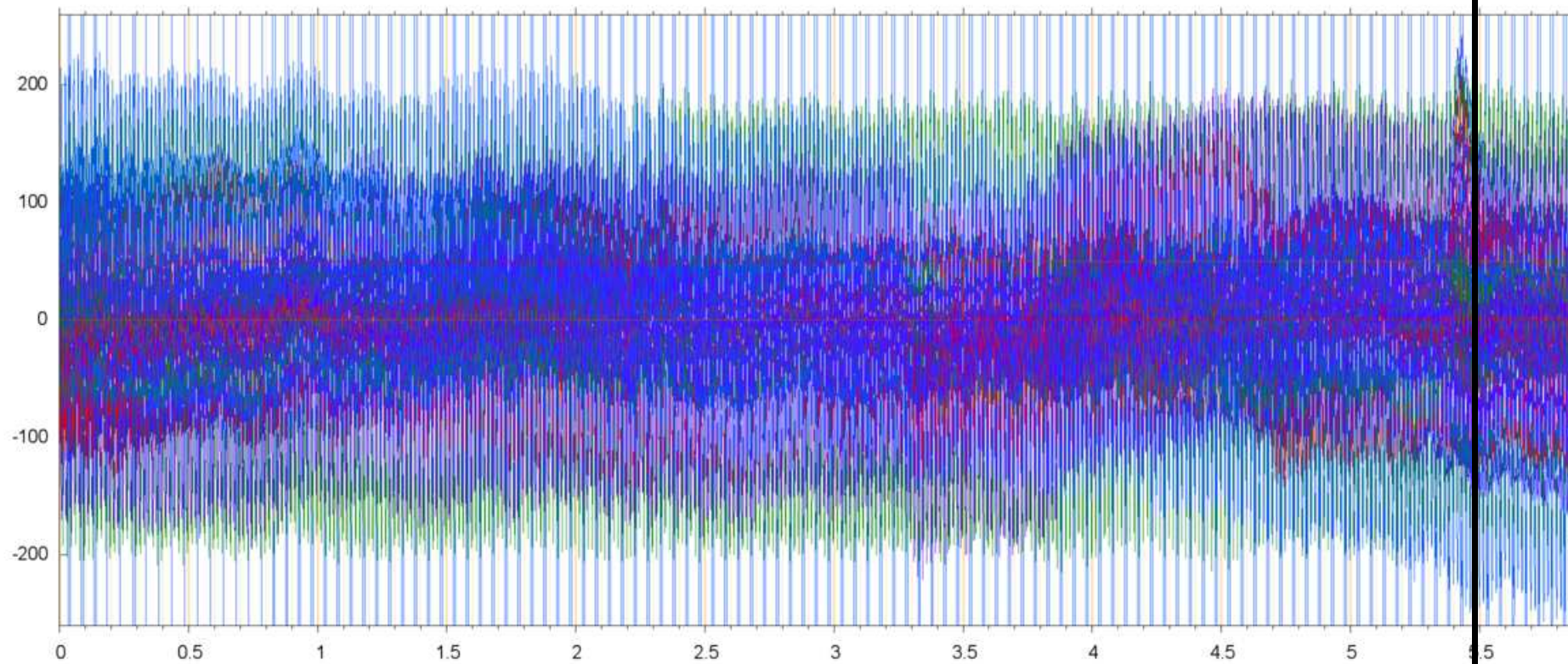
## Signal data:

1. 128 electrodes + reference (zero potential).

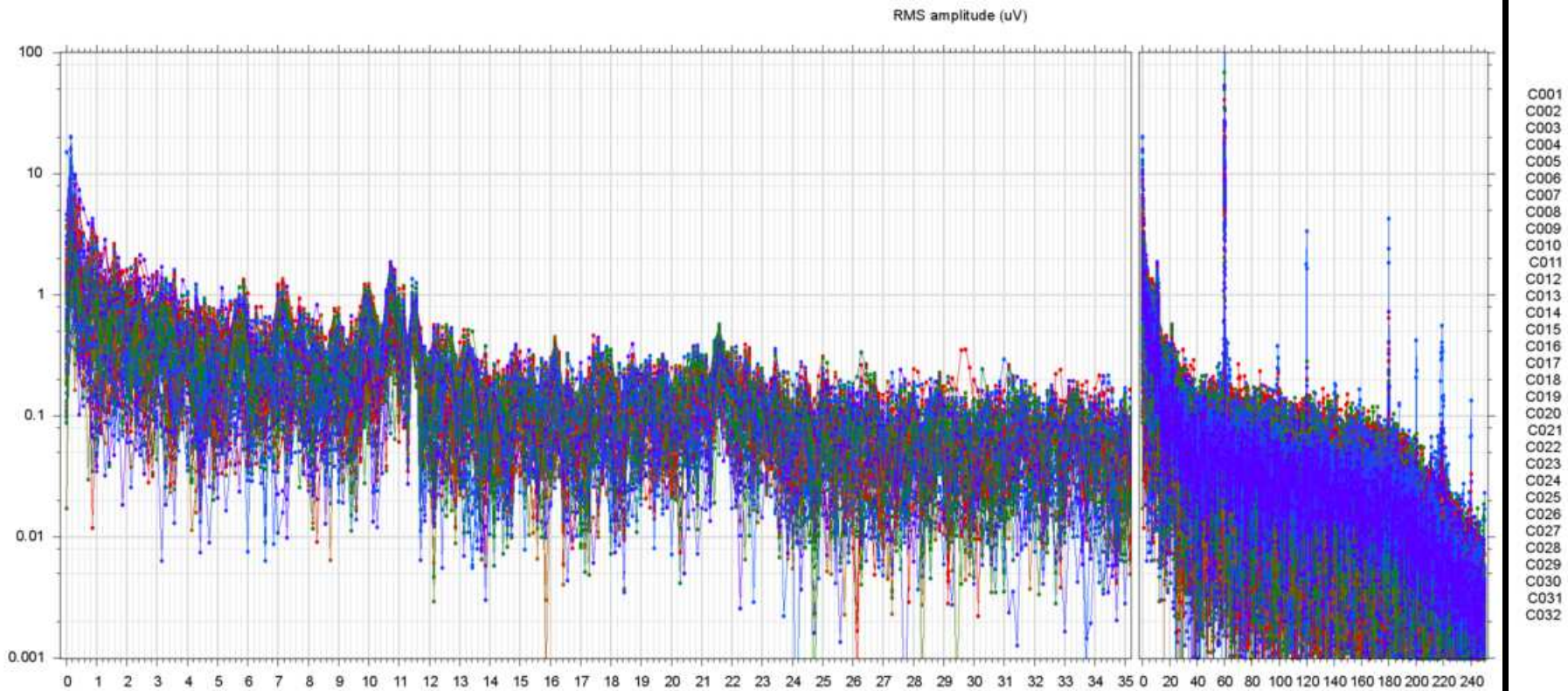


2. Sampling frequency 500 Hz.
3. Typical signal amplitudes  $< 100 \mu\text{V}$ .
4. Large and random offsets  $> 5000 \mu\text{V}$ .

Raw data for one run:

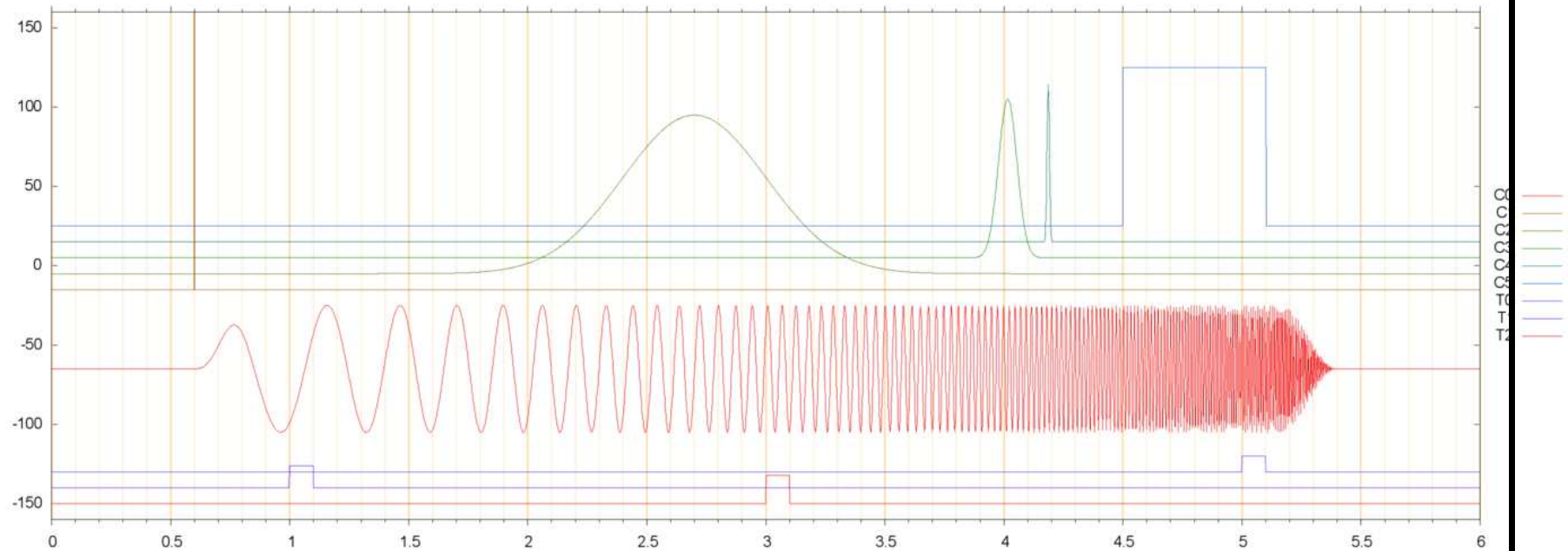


Power spectrum:



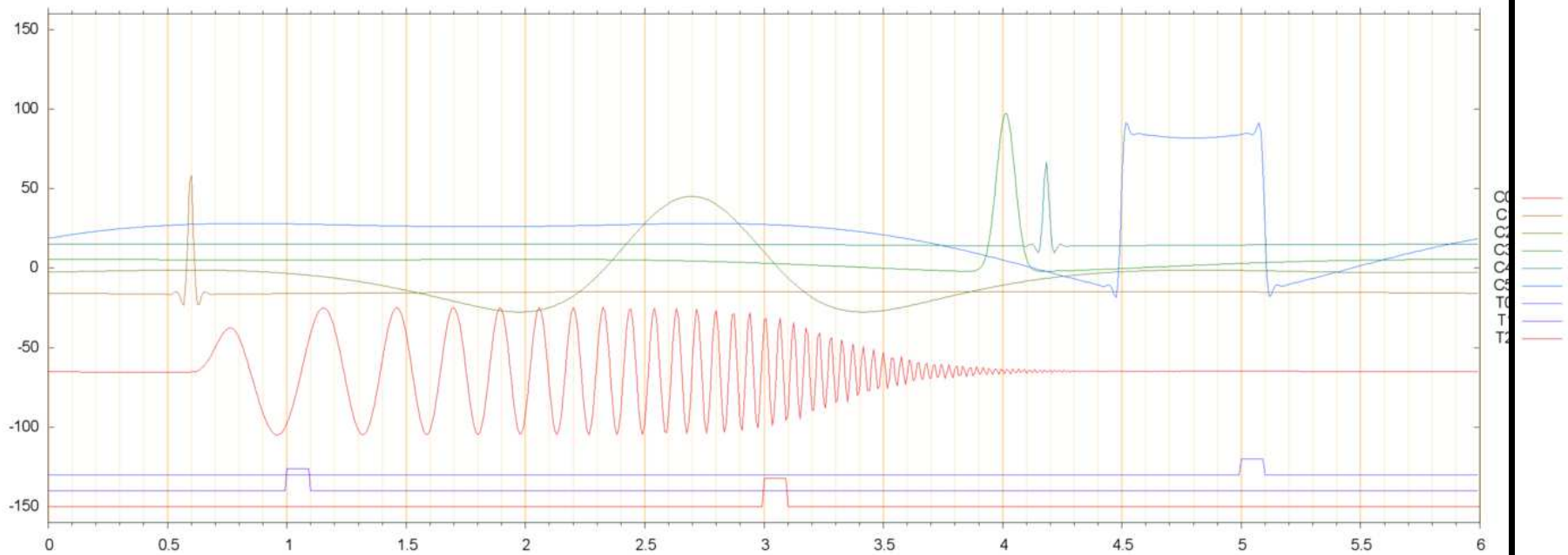
Note: logarithmic power scale.

Test signal:



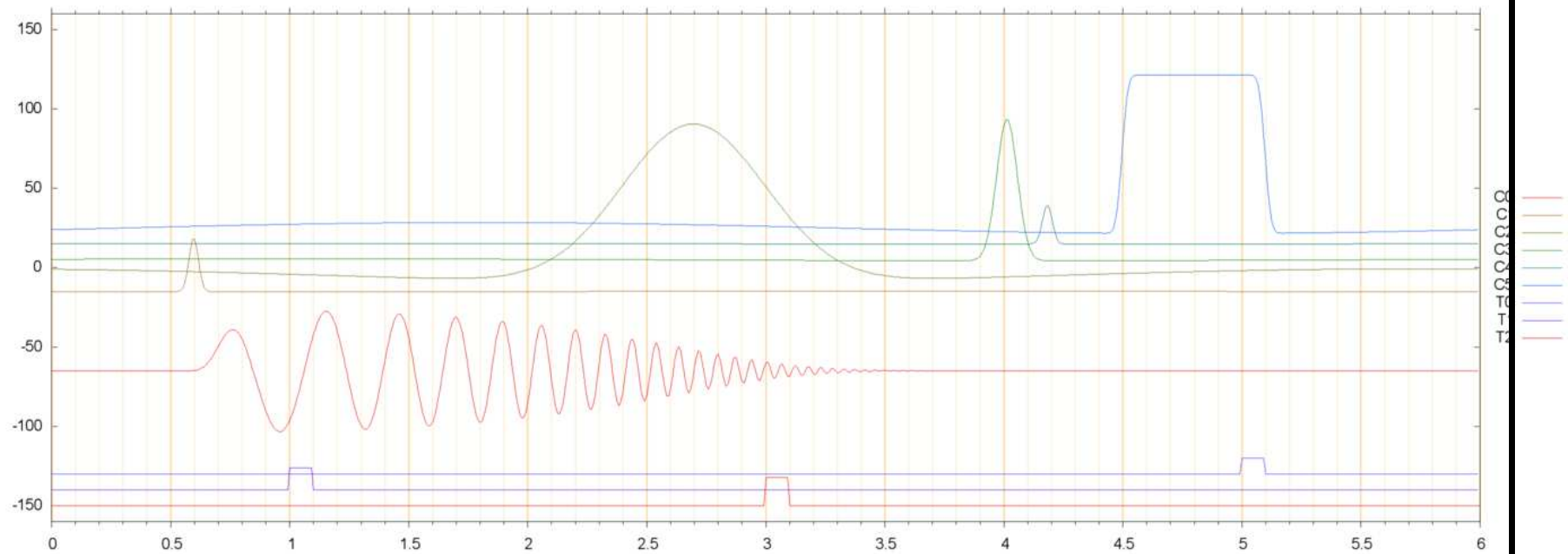


Butterworth 8-pole filter:

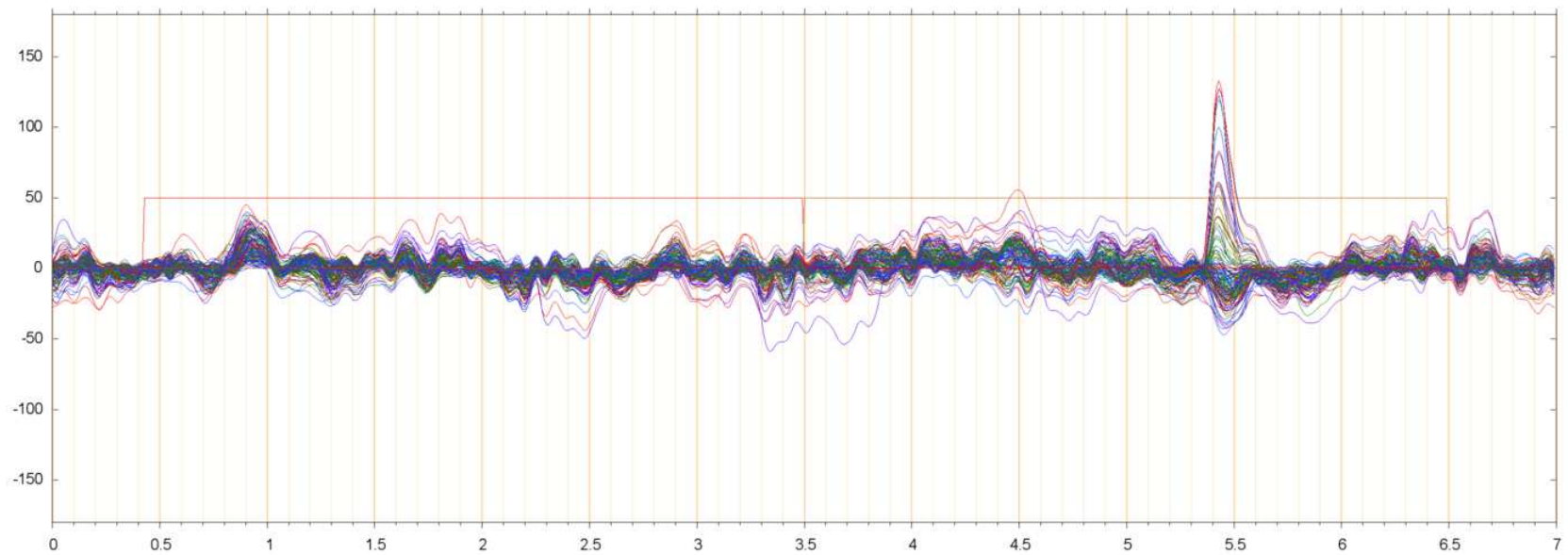


Note the ringing artifacts.

Gaussian filter:

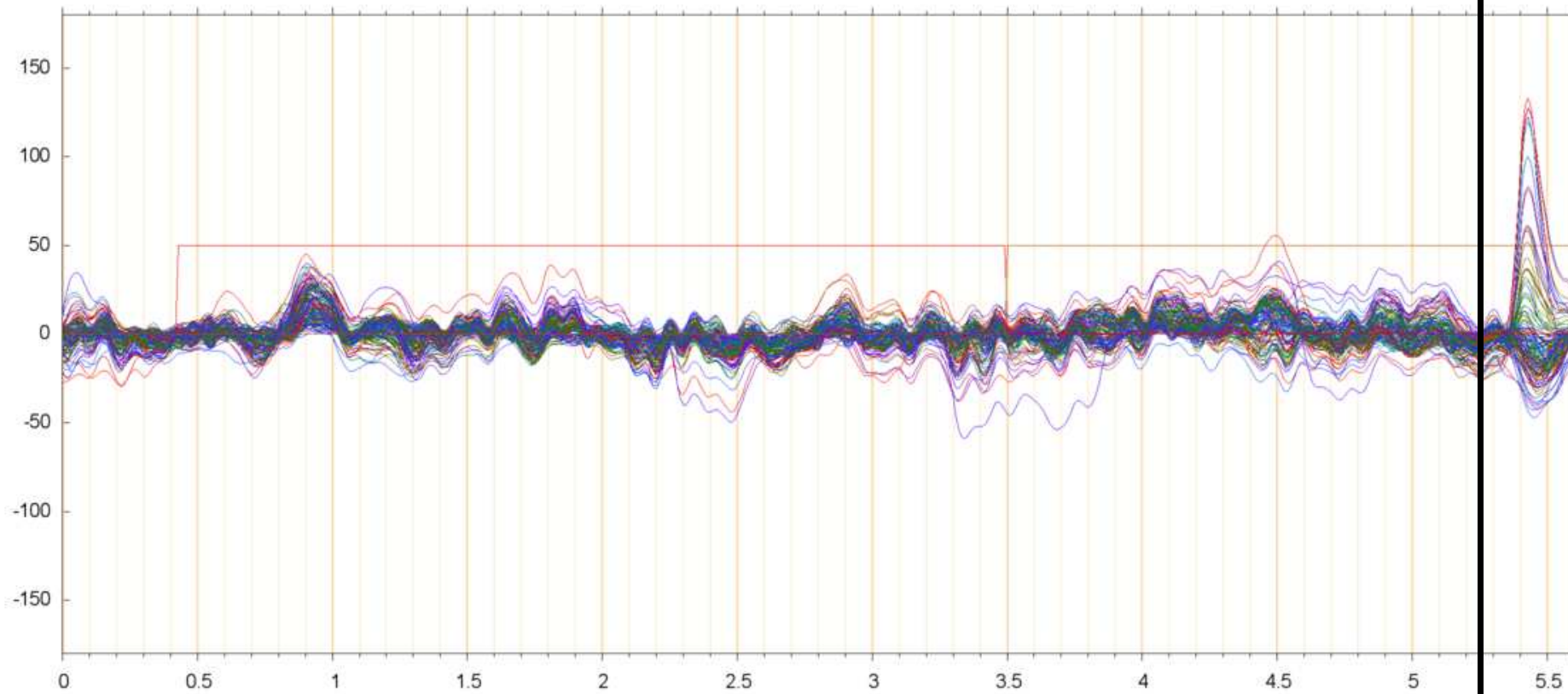


Filtered run:

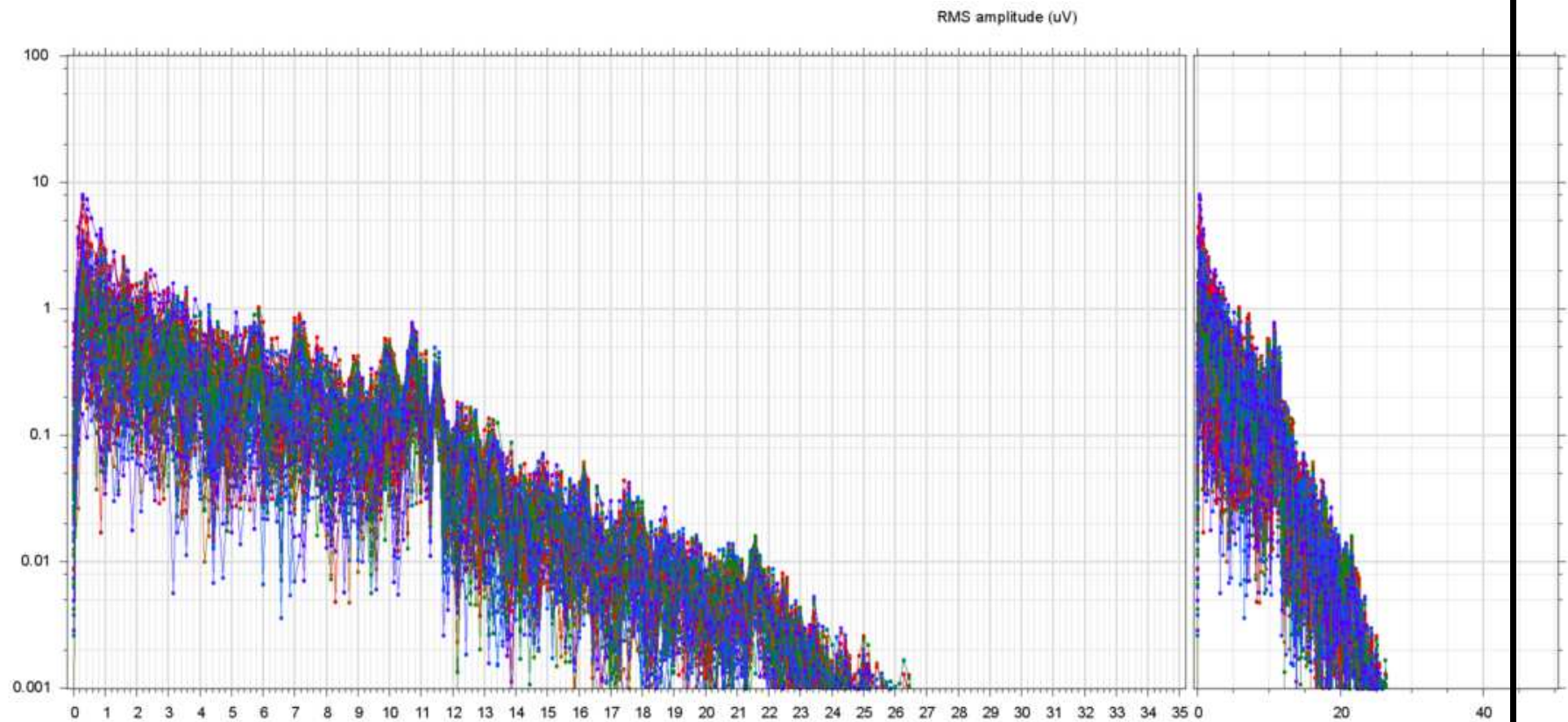




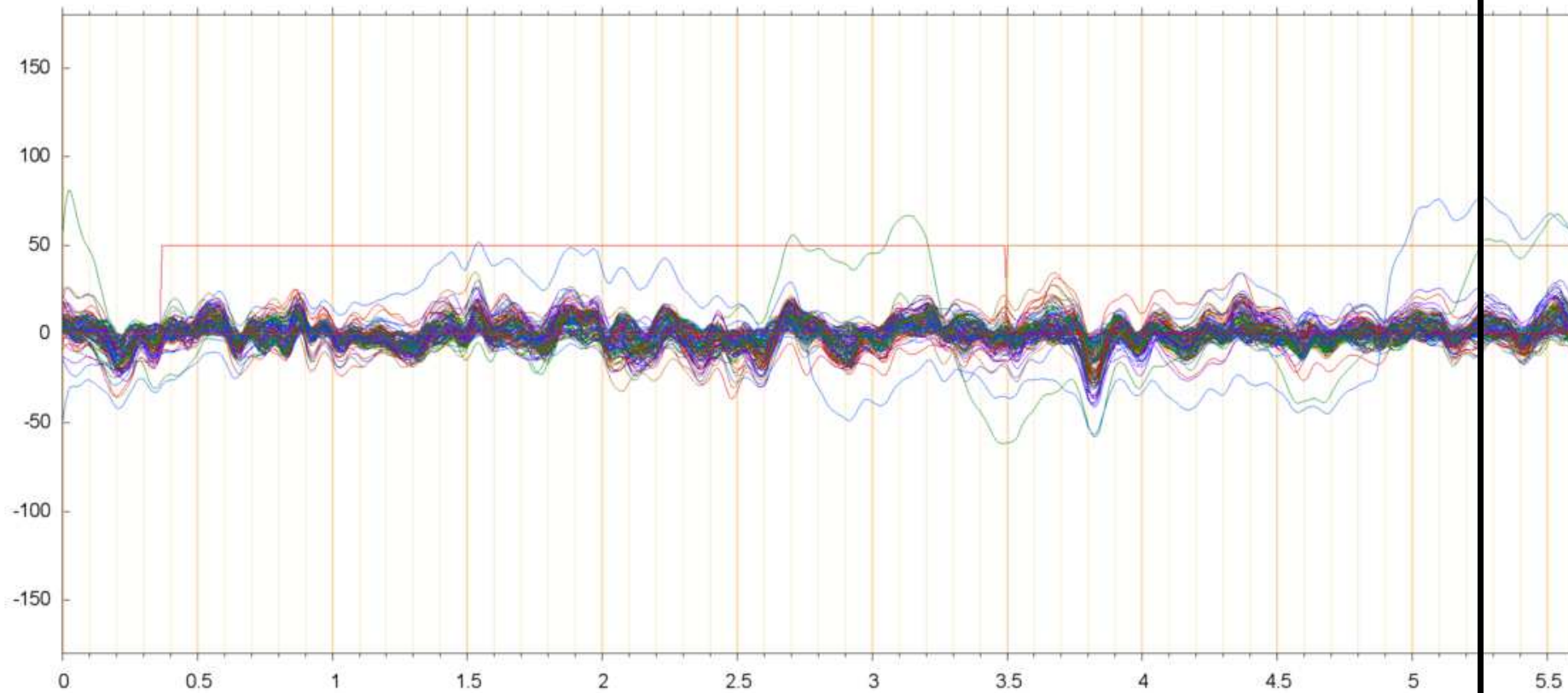
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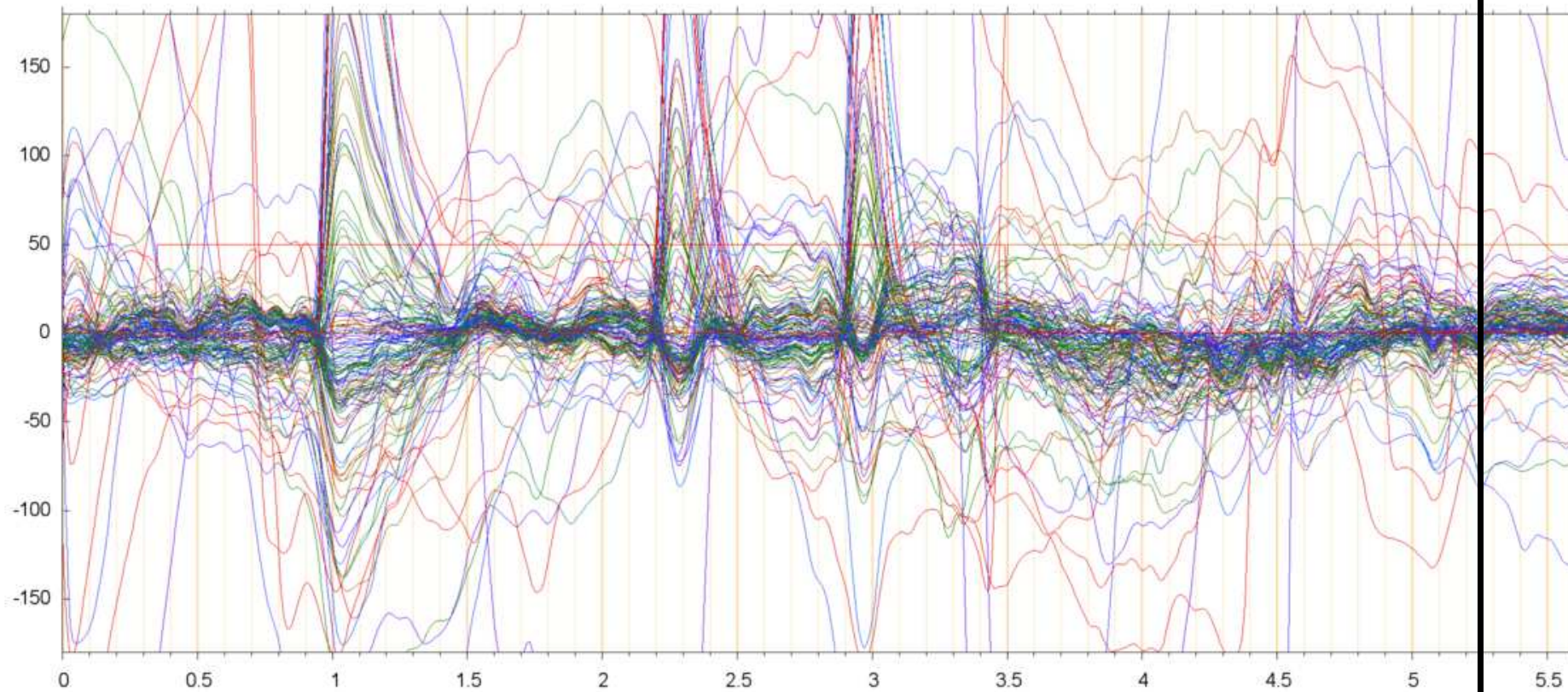
Power spectrum of filtered run (s013-00209):



Another filtered run:

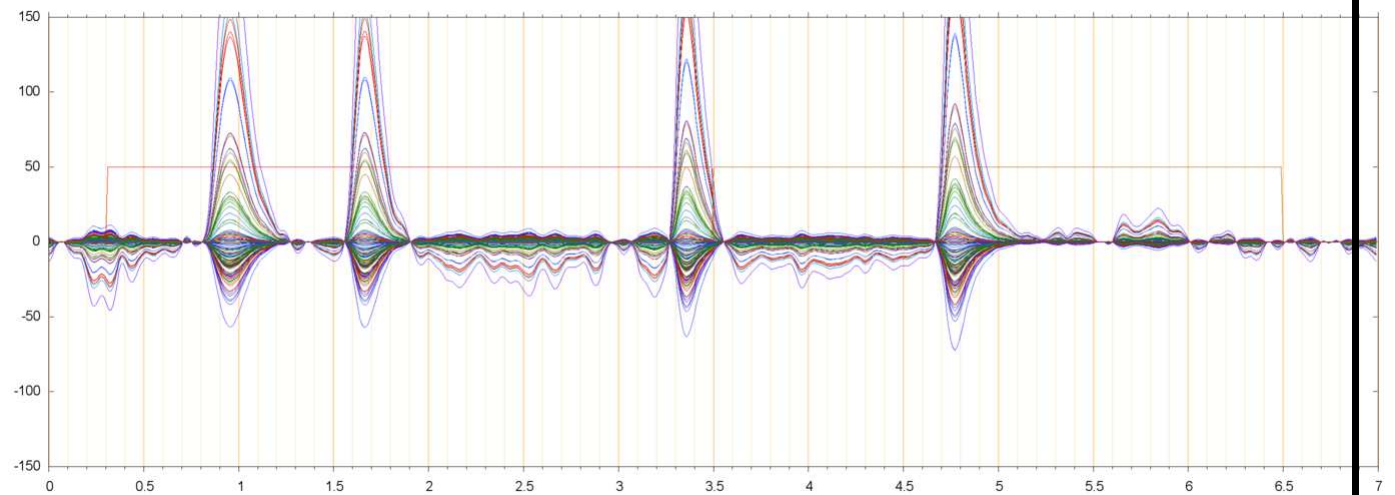
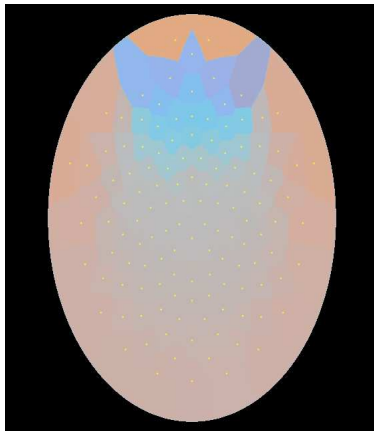


Another filtered run:

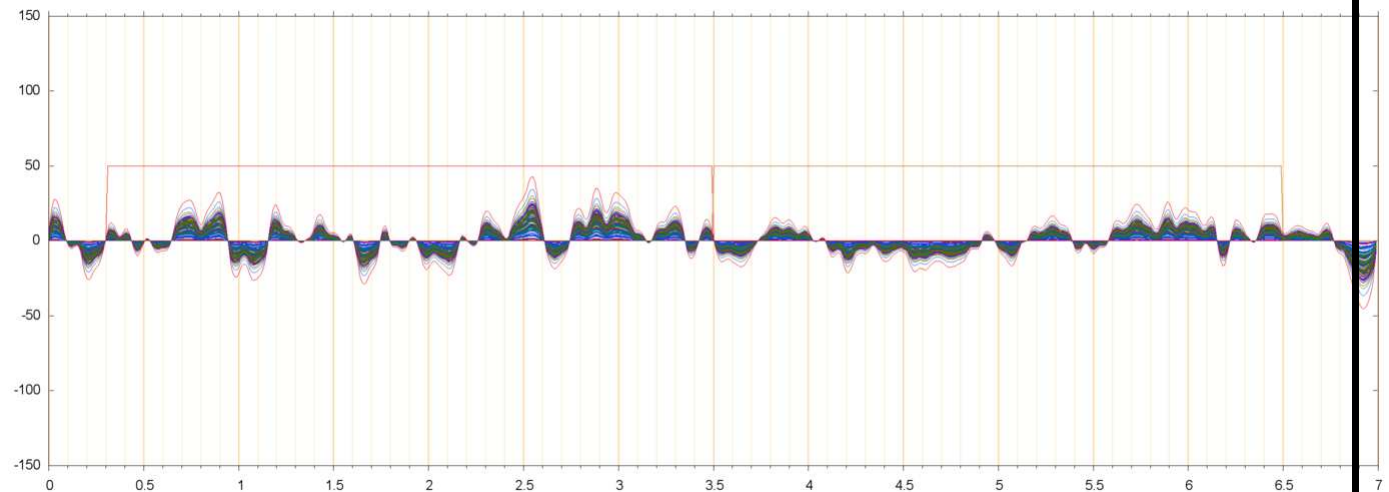
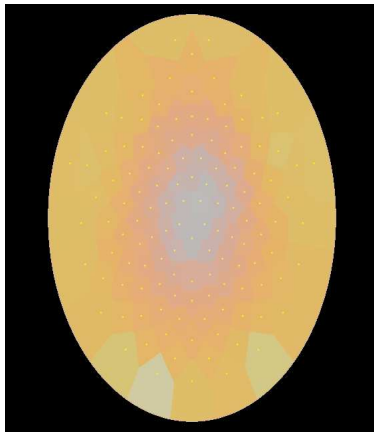


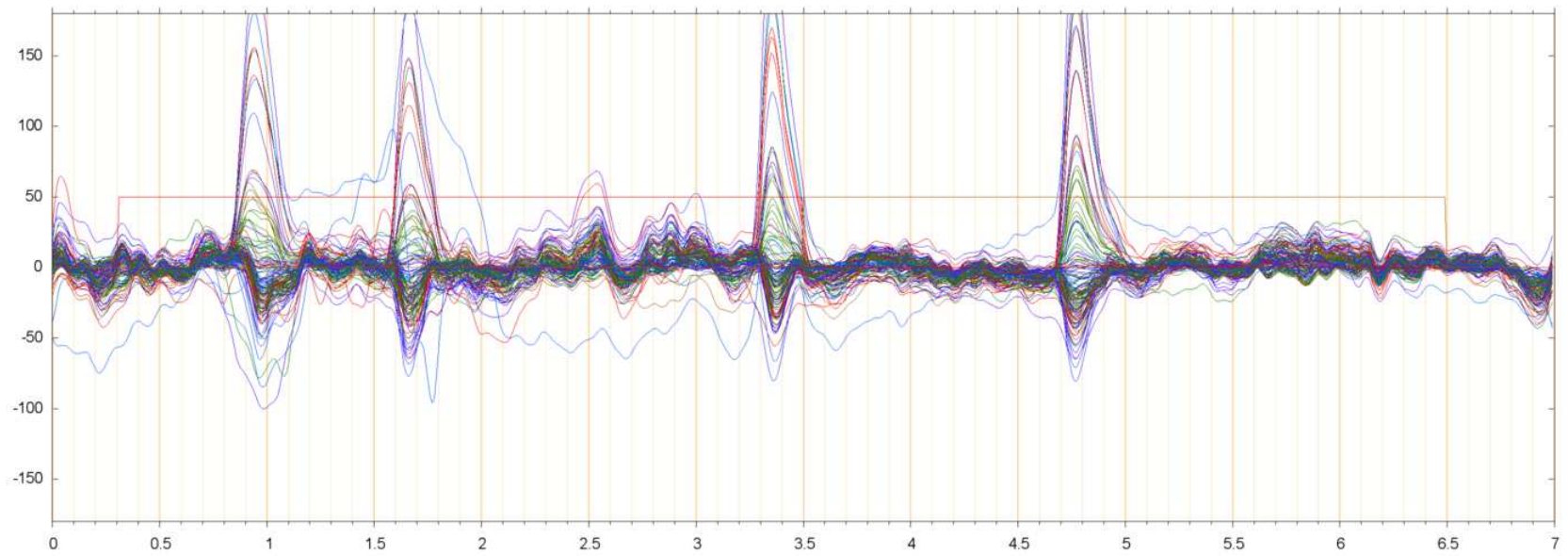


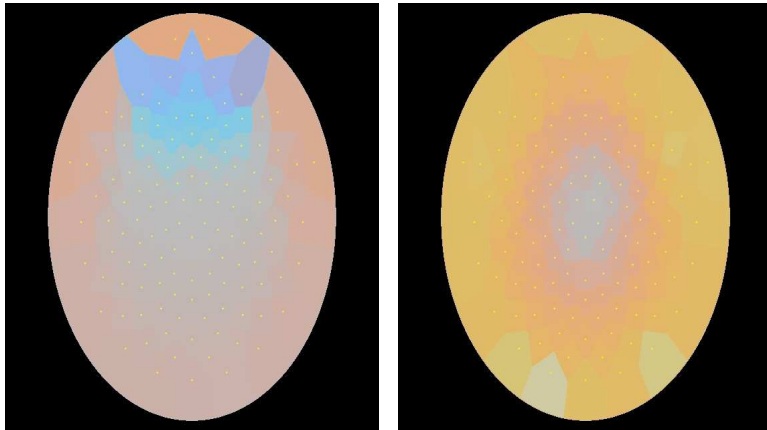
Blinks have a well-defined pattern that can be removed with PCA:



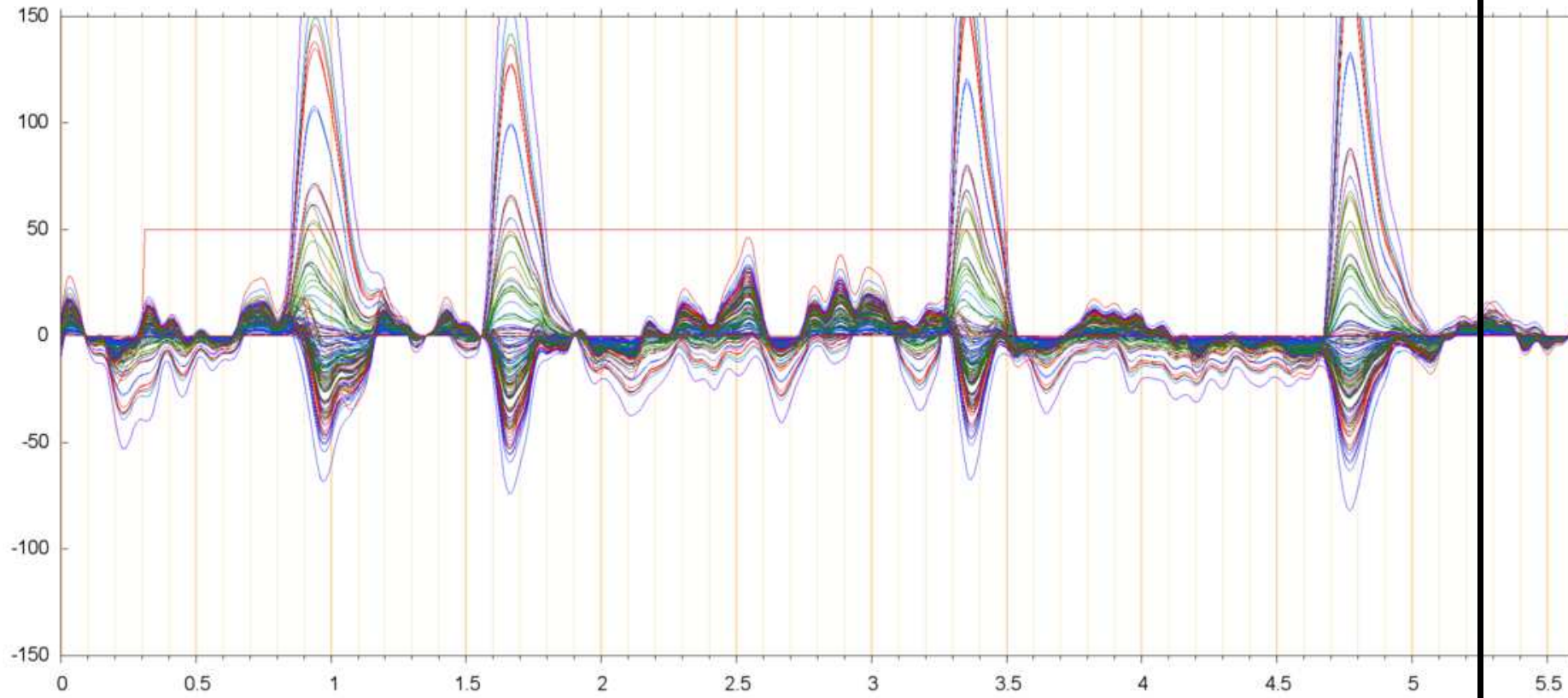
The second PCA component is a pulsating vertical gradient that oscillates irregularly with frequency  $\sim 10$  Hz:

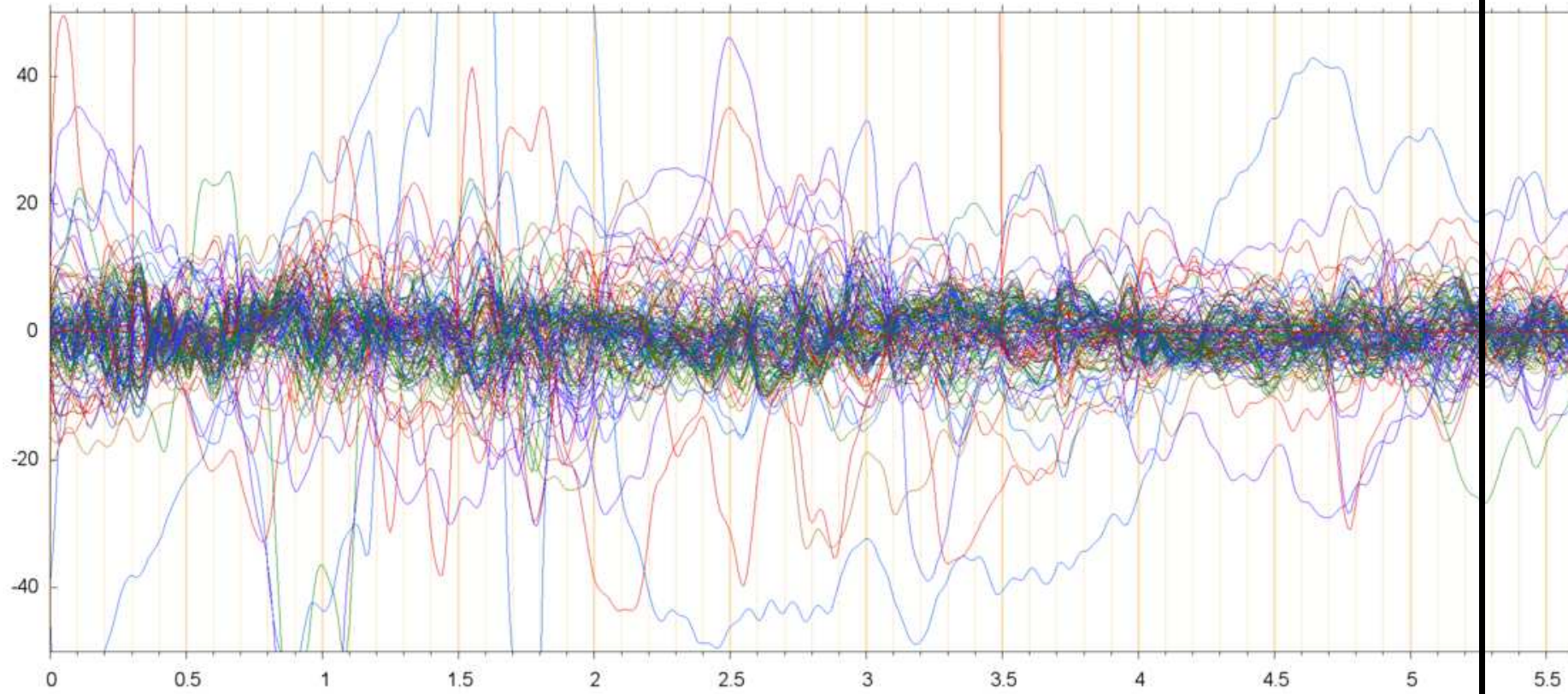












- One should always look closely at the data.
- This EEG data will need a lot of cleanup and processing before it can be used for structural analysis.
- Hardware prevention is better than software cure.