Electrodes checking and benchmark

Here below we perform the evaluation of the quality of the different electrodes from OPENBCI

* Passive flat OPENBCI
* Passive spike
* Active with cover
* Active without cover

EVALUATION

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ELECTRODE | MEAN | STD | RMS | PeaktoPeak | SNR | PSD comments |
| Passive flat  FP1 | -0.019767142869325304 | 19.441890129953585 | 19.441900178869446 | 163.35933839670867 | 5.269960579519166 | ok |
| Passive spike  FP2 | 0.011119395900497892 | 16.92560446915362 | 16.925608121636227 | 149.47619372305923 | 4.305468700433664 | ok |
| Active cover | 1.9503003998366368 | 41.05378283425904 | 41.10008219763198 | 183.25825342366613 | 9.834275567629435 | ok |
| Active without cover | 0.3070676231741368 | 41.26533979035388 | 41.26648226513334 | 182.16647383336698 | 10.7277988060442 |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

***UPDATE SNR is not a good metric, because we can not separate the noise from the good dataas it is real signal***

1. **Active without cover** (SNR ≈ 10.7 dB)
2. **Active with cover** (SNR ≈ 9.8 dB)
3. **Passive flat (FP1)** (SNR ≈ 5.3 dB)
4. **Passive spike (FP2)** (SNR ≈ 4.3 dB)

5 neoxa

* 5 reference kits
* 25 electrodes
* 5 boards cyton

SPECS

The ThinkPulse™ EEG sensor, developed by Conscious Labs, is an active dry electrode designed for long-term electroencephalographic (EEG) recording through hair, without the use of conductive gels.

The sensor consists of three primary components:

* **Dry Polymer Comb Disk:**  
  A scalp-contacting disk made from conductive polymer. Its comb-like design allows it to bypass hair and establish direct skin contact.
* **Embedded Active Circuit:**  
  Includes an impedance-matching **amplifier circuit** that amplifies the EEG signal at the source. This minimizes signal loss due to impedance mismatches with the acquisition system.
* **Shielded Cable with 2.54 mm Dupont Connector:**  
  Reduces electromagnetic noise and ensures clean signal transmission.

### **Electrical Characteristics**

* **Input Impedance:** 10 MΩ
* **Power Supply:**
  + V+ (Red): +2.5 V
  + V– (Black): –2.5 V
* **Output (White):** Vout – EEG analog signal output

The embedded circuit includes a body-safe resistor, a decoupling resistor, and a stabilizing capacitor for power regulation and safety. It is compatible with standard analog front ends for EEG acquisition.

TRIAL 29 APRIL

Test open eyes and eyes closed, the following electrodes are tested:

Af7 1

Fp1 2

Fp2 4

Af8 3

The reference and the ground are positioned on the front

SIGNAL TO NOISE RATIO

<https://psychology.stackexchange.com/questions/8930/how-is-the-signal-to-noise-ratio-of-an-event-related-potential-measured#:~:text=So%20SNR%20%3D%20signal%2Fnoise.,ERPamplitude%20%2F%20NOISEamplitude>).

<https://neuroimage.usc.edu/forums/t/compute-snr-in-eeg/19800>

**2 of May**

New function to check reliability of the signal, from last recordings

The function contains

return {

'alpha\_power': alpha\_power,

'beta\_power': beta\_power,

'delta\_power': delta\_power,

'line\_noise\_power': noise\_power,

'zero\_crossings\_per\_sec': zero\_crossings\_rate,

'percentage\_flatline': flatline\_ratio \* 100,

'large\_jumps': large\_jumps,

'range\_uV': signal\_range,

'symmetry\_corr\_LR': symmetry\_corr

}

**Guide of values**

| **Metric** | **Expected Range / Threshold (Good Signal)** | **Notes** |
| --- | --- | --- |
| alpha\_power (8–12 Hz) | 20–100+ µV² | Higher with **eyes closed**; dominant in occipital regions. |
| beta\_power (12–30 Hz) | 10–50 µV² | Increases with **concentration** or **alertness**. Too high = possible muscle artifacts. |
| delta\_power (0.5–4 Hz) | < 50 µV² (awake) | High values in awake state often indicate **motion artifacts** or drowsiness. |
| line\_noise\_power (~50/60 Hz) | < 10 µV² | Higher = **electrical interference** (bad grounding, nearby devices). |
| zero\_crossings\_per\_sec | 30–70 /sec | Low = flatline or very slow waves; very high = noise or muscle activity. |
| percentage\_flatline | < 1% | High flatline = **disconnected or failing electrode**. |
| large\_jumps | 0–2 | More than 2 often indicates **movement artifacts** or signal dropouts. |
| range\_uV | 30–150 µV | <30 µV = weak signal; >150 µV = possible artifact (e.g., blinks, EMG). |
| symmetry\_corr\_LR | 0.7 – 1.0 | Low correlation may indicate bad electrode, asymmetry, or pathology. |

Recordings performed on Laura

**Passive 2**

Fp1

{'alpha\_power': np.float64(49.247453427987814),

'beta\_power': np.float64(57.596345471291805),

'delta\_power': np.float64(381.37676186173985),

'line\_noise\_power': np.float64(28.602145456259244),

'zero\_crossings\_per\_sec': np.float64(41.7735728030789),

'percentage\_flatline': np.float64(0.0),

'large\_jumps': np.int64(4),

'range\_uV': np.float64(144.14808366179327),

'symmetry\_corr\_LR': np.float64(1.0)}

Fp2

{'alpha\_power': np.float64(60.959852637157354),

'beta\_power': np.float64(58.39745191344101),

'delta\_power': np.float64(693.7056704315235),

'line\_noise\_power': np.float64(22.850942016391844),

'zero\_crossings\_per\_sec': np.float64(35.07857601026299),

'percentage\_flatline': np.float64(0.0),

'large\_jumps': np.int64(0),

'range\_uV': np.float64(170.33649514199607),

'symmetry\_corr\_LR': None}

Comments

* Delta activity, large jumps in fp1, and high line noise may suggest that there are many motion artifacts, lack of stability (motion) and the pollution of other electronic devices around ( maybe the computer was plugged in)

**Passive 2**

Fp1

{'alpha\_power': np.float64(49.247453427987814),

'beta\_power': np.float64(57.596345471291805),

'delta\_power': np.float64(381.37676186173985),

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'range\_uV': np.float64(170.33649514199607),

'symmetry\_corr\_LR': None}

Comments

* Delta activity, large jumps in fp1, and high line noise may suggest that there are many motion artifacts, lack of stability (motion) and the pollution of other electronic devices around ( maybe the computer was plugged in)

**Active**

{'alpha\_power': np.float64(17.973991424316292),

'beta\_power': np.float64(38.38075479369182),

'delta\_power': np.float64(127.36544384396936),

'line\_noise\_power': np.float64(1.3786115713154299),

'zero\_crossings\_per\_sec': np.float64(41.145332050048125),

'percentage\_flatline': np.float64(0.0),

'large\_jumps': np.int64(0),

'range\_uV': np.float64(144.15823776899754),

'symmetry\_corr\_LR': np.float64(0.9999999999999999)}

Comments

* Delta activity, not high line noise. It may suggest that there are many motion artifacts, lack of stability (motion), but lower than passive.

Reference

alpha\_power': np.float64(5.653895086871416),

'beta\_power': np.float64(19.672040425075394),

'delta\_power': np.float64(32.70245395931612),

'line\_noise\_power': np.float64(1.3188083951309895),

'zero\_crossings\_per\_sec': np.float64(75.6639194139194),

'percentage\_flatline': np.float64(22.74496336996337),

'large\_jumps': np.int64(0),

'range\_uV': np.float64(69.04058376551578),

* NO electrical interference, good signal range and no jumps
* Problems with flatline ( lost signal due to bad connection of the electrode)
* High delta power that could be artifacts or other interferences (we may filter that, but the signal may not be really exploitable)

Tuesday 13, checking cables 28 AWG

<https://raphaelvallat.com/bandpower.html>

We performed a test in different conditions, chewing, sitting, and moving ( drinking)

Observations:

* The signal looks good at a glance, big artifacts in some cases and noise
  + Sitting; high alpha 899
  + Drinking good results for alpha 256 uV^2
  + Chewing super high alpha 956.373 uV^2
  + Moving 229
* High alpha could be due to
  + muscular noise (chewing makes sense) Goncharova et al. (2003) "EMG contamination of EEG: spectral and topographical characteristics." Clinical Neurophysiology.
  + High impedance, noisy, fluctuations
  + Eye movements

However there are not irregular peaks, so it seems that the power is not due to the noise

RATIOS

28 awg cable

Ratio noise

{'delta': 10.42660803445047, 'theta': 8.45974512055265, 'alpha': 11.308863368577981, 'beta': 3.5703373259339912}

Relative alpha power: 0.290

Absolute alpha power: 797.408 uV^2

28 awg cable sitting

Ration noise

{'delta': 5.407586929344589, 'theta': 12.753172949750335, 'alpha': 12.688631199155404, 'beta': 3.4781291641666248}

Relative alpha power: 0.323

Absolute alpha power: 742.494 uV^2

Normal cable

Alpha absolute 15.716 uV^2

Relative alpha power: 0.083

{'delta': 0.8862089828897834, 'theta': 2.8634492612377445, 'alpha': 0.5785318213273, 'beta': 0.6706881977380555}

Steps:

* Noise, computing PSD superior to 55Hz, normal cables exhibit a more robust signal ( less noise in the high frequency range)
* When computing the ratios, power band to noise, the observed values in the normal bands vary a lot. The passive recording exhibit ‘ ordinary values’ according to some literature extractions ( we need to take into account that the systems are different). For the 28 AWG cable, the ratios are bigger, showing that the psd in the bands is higher than expected
* Visual exploration show that the signal looks good, but more metrics are needed
* <https://sci-hub.sidesgame.com/10.1007/s12206-011-0128-2>

14 MAY NEW TEST

* 3 recordings each, at the same time
* Average of 3 recordings
* Visual inspection
* Noise ratio
* Alpha, beta bands
* Noise inspection
* Other metrics
* 3 eyes closed
* 3 eyes open
* Offset was calculated simply by averaging the signal over the whole recording time.
* Baseline drift obtained by subtracting the offset of two 1 s intervals, one at the beginning of the signal and the other at 1 min later.
* Baseline noise power was also measured, as the power of the signal at the frequencies between 0.3 and 0.7 Hz since possible oscillations in the signal baseline may not reflect in the calculated offset and drift. The chosen frequency band covers the main part of the baseline noise spectrum but just a negligible amount of the primary signal's spectrum.
* 50-Hz noise amplitude was calculated by first applying a bandpass filter with cutoff frequencies of 45 and 55 Hz and then obtaining the power of the signal at its peak frequency with a bandwidth of 1.6 Hz. Finally, the amplitude of sinusoidal power line interferences was determined using Eq. 2:
* Similarity describes how similar two signals are. After filtering DC components of the two intended signals, the Pearson's r-squared (C) was calculated for the filtered signals and their PSDs, to determine time and frequency domain similarities, respectively, according to Eq. 3:
* Similarity (%) =100 C2

<https://pmc.ncbi.nlm.nih.gov/articles/PMC5156995/>

CHOOSING BEST BETA IN ARTIFACT REMOVAL

- Pre- and post-filtering visualization

Plots the data before and after applying ATAR with different beta values. Look for excessive distortion or loss of brain signal.

- Comparison of power spectra

If you are interested in preserving certain bands (alpha, theta, etc.), check if the relative power in those bands changes significantly.

- Correlation between original and filtered signals

You can calculate the correlation between the signal before and after ATAR. If it drops too much with low beta values, you are removing too much.