

EEG Feature Extraction Reference

BCI Compatibility Predictor Features

This document provides a complete reference for all features extracted from the PhysioNet Motor Movement/Imagery EEG dataset for BCI compatibility prediction. Each feature includes the associated CSV columns, descriptions, and units.

1. Resting Alpha Power

Measured from eyes-closed baseline (R02 run)

- **rpl_alpha:** Relative Power Level for alpha band
 - Alpha power divided by total power (2-35 Hz)
 - Units: Ratio (unitless, 0-1 range)
- **resting_alpha_power:** Absolute alpha band power
 - Integrated power in 8-13 Hz frequency range
 - Units: V^2 (multiply by 10^{12} for μV^2)
- **resting_total_power:** Total broadband power
 - Integrated power across 2-35 Hz
 - Units: V^2 (multiply by 10^{12} for μV^2)

2. Resting Beta Power

Measured from eyes-closed baseline (R02 run)

- **rpl_beta:** Relative Power Level for beta band
 - Beta power divided by total power (2-35 Hz)
 - Units: Ratio (unitless, 0-1 range)
- **resting_beta_power:** Absolute beta band power
 - Integrated power in 13-30 Hz frequency range
 - Units: V^2 (multiply by 10^{12} for μV^2)

3. SMR Baseline Strength

Measured from eyes-open baseline (R01 run) using Laplacian filtering

- **smr_strength:** Peak height above 1/f noise floor
 - Maximum of SMR peaks (mu and beta) minus fitted noise spectrum

- Averaged across C3 and C4 Laplacian channels
- Units: dB (decibels)
- Higher values indicate stronger resting SMR rhythms

4. ERD/ERS Magnitude

Event-Related Desynchronization/Synchronization during motor tasks

Real Movement (R03 run):

- **mu_erd_real_C3, mu_erd_real_C4, mu_erd_real_Cz**
 - Minimum percent change in mu power (8-13 Hz) during real movement
 - Units: Percentage (%)
- **beta_erd_real_C3, beta_erd_real_C4, beta_erd_real_Cz**
 - Minimum percent change in beta power (13-30 Hz) during real movement
 - Units: Percentage (%)
- **mu_ers_real_C3, mu_ers_real_C4, mu_ers_real_Cz**
 - Maximum percent change in mu power during real movement
 - Units: Percentage (%)
- **beta_ers_real_C3, beta_ers_real_C4, beta_ers_real_Cz**
 - Maximum percent change in beta power during real movement
 - Units: Percentage (%)

Imagined Movement (R04 run):

- **mu_erd_imagined_C3, mu_erd_imagined_C4, mu_erd_imagined_Cz**
 - Minimum percent change in mu power during motor imagery
 - Units: Percentage (%)
- **beta_erd_imagined_C3, beta_erd_imagined_C4, beta_erd_imagined_Cz**
 - Minimum percent change in beta power during motor imagery
 - Units: Percentage (%)
- **mu_ers_imagined_C3, mu_ers_imagined_C4, mu_ers_imagined_Cz**
 - Maximum percent change in mu power during motor imagery
 - Units: Percentage (%)
- **beta_ers_imagined_C3, beta_ers_imagined_C4, beta_ers_imagined_Cz**
 - Maximum percent change in beta power during motor imagery
 - Units: Percentage (%)

Note: Negative values indicate desynchronization (ERD), positive values indicate synchronization (ERS)

5. Power Spectral Entropy (PSE)

Measured from eyes-open baseline (R01 run) in SMR range (8-30 Hz)

- **pse_C3**: Spectral entropy for channel C3
- **pse_C4**: Spectral entropy for channel C4
- **pse_Cz**: Spectral entropy for channel Cz
- **pse_FC1**: Spectral entropy for channel FC1
- **pse_FC2**: Spectral entropy for channel FC2
- **pse_CP1**: Spectral entropy for channel CP1
- **pse_CP2**: Spectral entropy for channel CP2
- **pse_avg**: Average spectral entropy across all motor channels
 - Measures how uniformly power is distributed across frequencies
 - Units: Normalized entropy (0-1 range)
 - Lower values = more organized/rhythmic signal
 - Higher values = more chaotic/noisy signal

6. Lempel-Ziv Complexity (LZC)

Measured from eyes-open baseline (R01 run) after 2-35 Hz filtering

- **lzc_C3**: LZ complexity for channel C3
- **lzc_C4**: LZ complexity for channel C4
- **lzc_Cz**: LZ complexity for channel Cz
- **lzc_FC1**: LZ complexity for channel FC1
- **lzc_FC2**: LZ complexity for channel FC2
- **lzc_CP1**: LZ complexity for channel CP1
- **lzc_CP2**: LZ complexity for channel CP2
- **lzc_avg**: Average LZ complexity across all motor channels
 - Measures temporal complexity of binarized EEG signal
 - Units: Normalized complexity (0-1 range)
 - Lower values = more regular/predictable patterns
 - Higher values = more complex/irregular patterns

7. Theta/Alpha Ratio

Measured from eyes-open baseline (R01 run)

- **theta_power**: Absolute theta band power
 - Integrated power in 4-8 Hz frequency range
 - Units: V^2 (multiply by 10^{12} for μV^2)

- **alpha_power**: Absolute alpha band power (from R01)
 - Integrated power in 8-13 Hz frequency range
 - Units: V^2 (multiply by 10^{12} for μV^2)
 - Note: *Different from resting_alpha_power (which uses R02)*
- **theta_alpha_ratio**: Ratio of theta to alpha power
 - $\text{theta_power} / (\text{alpha_power} + \text{epsilon})$
 - Units: Ratio (unitless)
 - Lower values indicate better alertness/attention
 - Higher values may indicate drowsiness/fatigue

Quick Reference Summary

Total CSV Columns: 49 feature columns + 1 subject_id column

Important Notes on Units

Power Values (V^2 to μV^2):

- All power values are in V^2 (Volts squared)
- To convert to μV^2 (microvolts squared): multiply by 10^{12}
- Example: $4.35 \times 10^{-10} V^2 = 435 \mu V^2$

Typical Value Ranges:

- Alpha power (eyes closed): 100-1000 μV^2
- Total power (2-35 Hz): 500-5000 μV^2
- SMR strength: 1-15 dB
- ERD magnitude: -50% to -90% (negative indicates desynchronization)
- PSE: 0.7-1.0 (higher = more chaotic)
- Theta/Alpha ratio: 0.1-2.0 (lower = more alert)

Data Source

Dataset: PhysioNet EEG Motor Movement/Imagery Dataset

- R01: Eyes-open baseline (1 minute)
- R02: Eyes-closed baseline (1 minute)
- R03: Real left/right fist movements
- R04: Imagined left/right fist movements
- Sampling rate: 160 Hz
- Channels: 64 EEG channels (10-20 system)