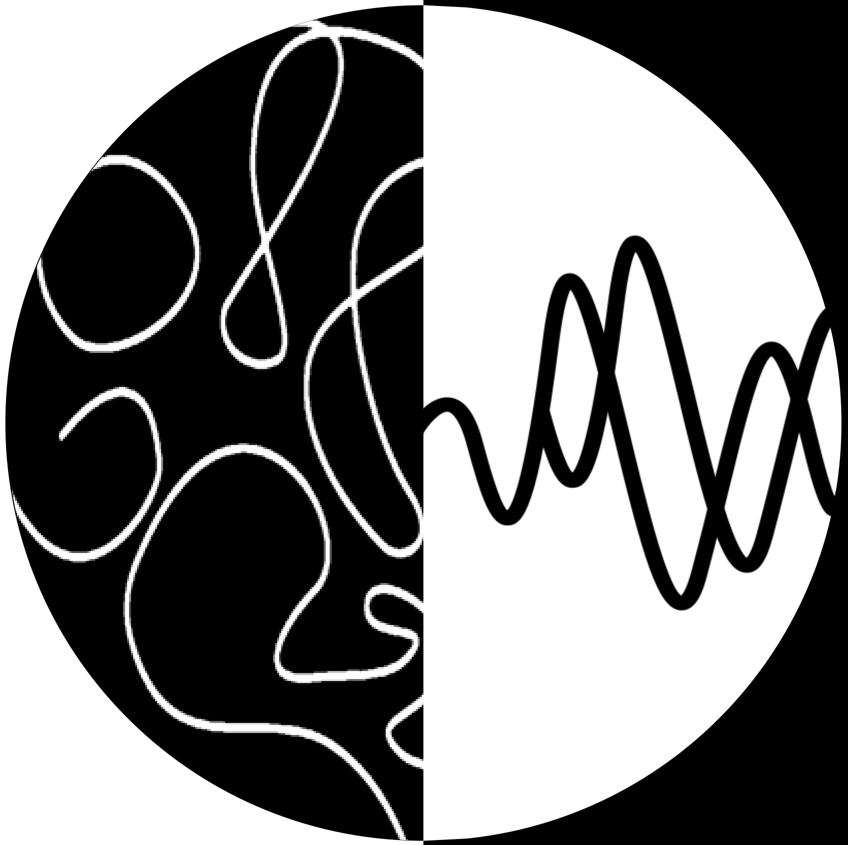
AmberGlasses:

a standalone modularized light-weighted BCI device



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Traditional steady state visually evoked potentials (SSVEP) paradigms, which require users to gaze at a visual stimulus with both eyes, restricts its applicability in real-world scenarios.

Minimize Visual Interference

+

Ensure Signal Quality

→

Amber Glasses

Design

AG is a 3D-printed EEG-based BCI device that features a **portable**, **standalone**, and **monocle** design.

1. Transparent Display
2. EEG Dry Electrodes (Forehead)
3. EEG Electrode Holder
4. Rotatable Strap Holder
5. EEG Expansion Module

Digital Fabrication

The prototype is 3D-printed using a FDM printer.

Adjustable strap length to fit different head size

Rotatable joints to adjust angle position

Arc design increase durability and maintain flexibility

Specifications

Dimension: 25 x 16 x 4 cm
Visual Stimulation Range: 0-20Hz
Wireless Connection: WiFi 2.4GHz
Battery: Lithium Polymer battery 300mAh
Charging Interface: USB Type-C

	EEG Channels	Weight
Transparent Display Module	Fp1, Fp2	50g
Sensing Headset	O1, Oz, O2	30g (w/o electrodes)
EEG Expansion Module	Flexible adjustment from Frontal to Parietal	10g (w/o electrodes)

EEG Expansion Module

Amber Glasses, consisting of a sensing headset, a display module, and an EEG expansion module, is designed to accommodate a wide range of use cases that require mobile EEG capabilities.

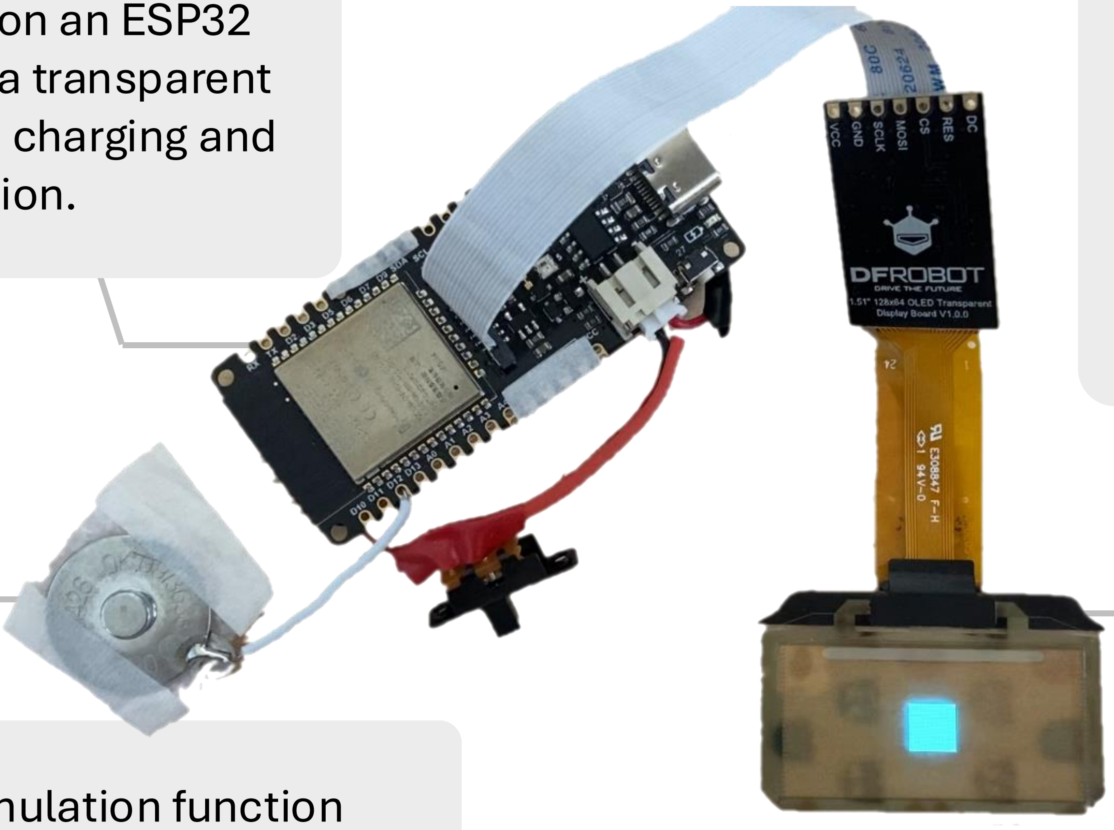
Rotation Joint at 0°

The expansion module covers 3 additional channels spanning from the **frontal lobe** to the **parietal lobe** by a rotating joint.

Rotation Joint at 90°

Display Module

The module is developed on an ESP32 board and equipped with a transparent screen, supporting type-c charging and wireless network connection.



The transparent screen can provide a **0-20Hz** visual stimulation display or be used as a basic operating interface without blocking the user's line of sight.

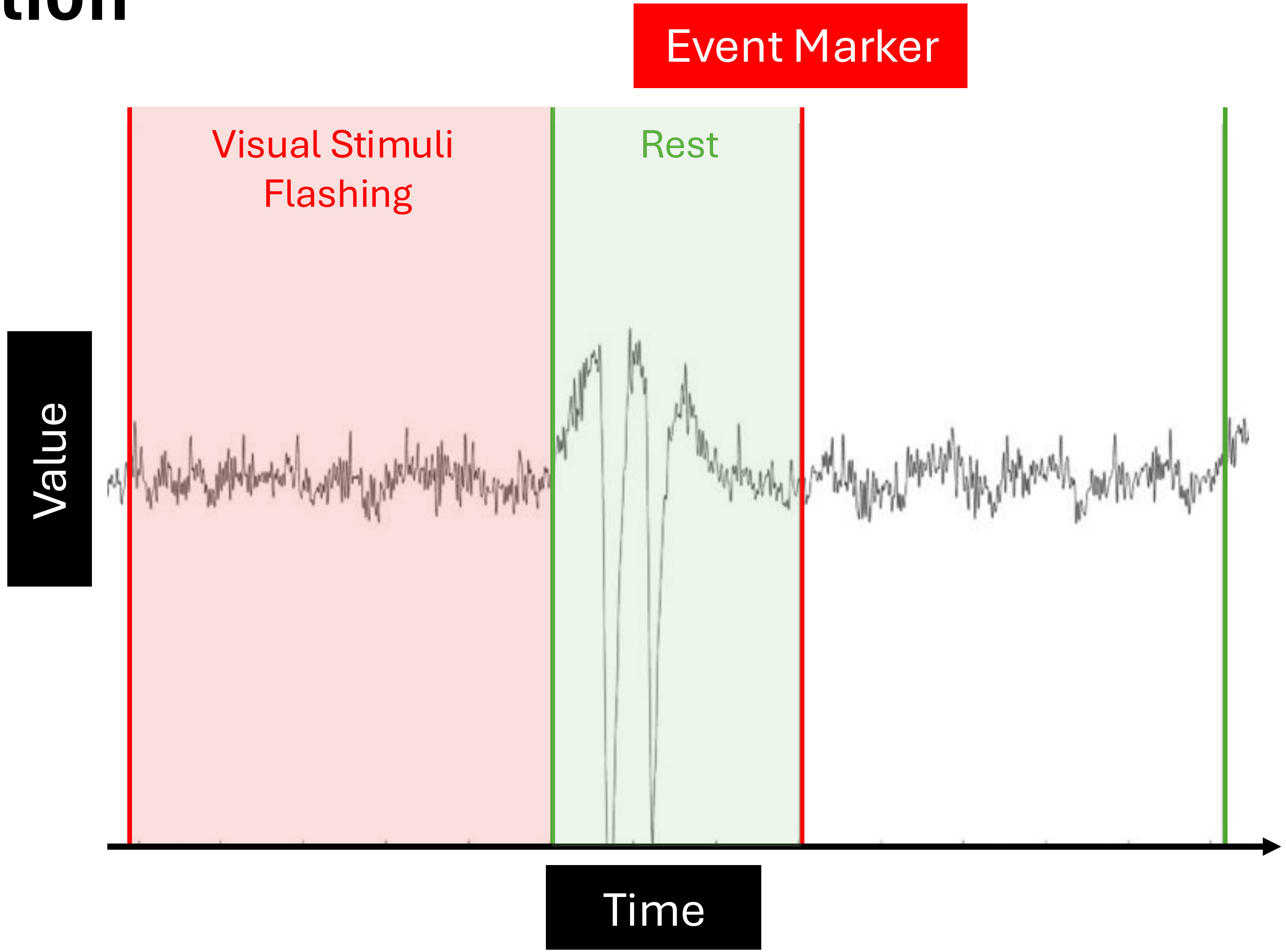
The user can start the stimulation function themselves by touching the capacitive touch sensor during operation.

EEG Data Extraction

Bandpass Filter

Select Data (channel, event)

Fast Fourier Transform



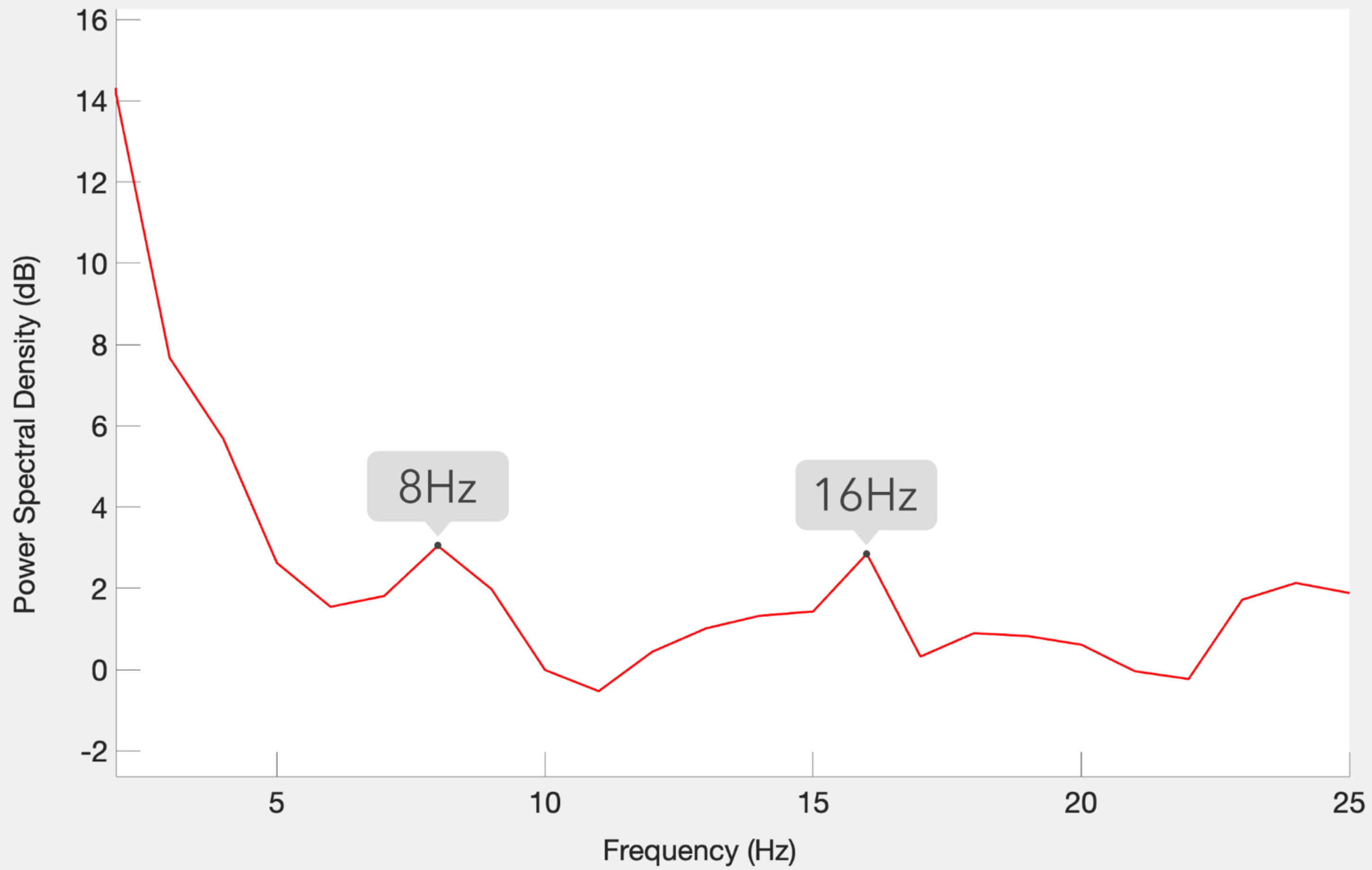
Use Case - Person Identification

SSVEP Signal → Classification → Authenticated / Rejected

- How do we verify signal quality?
- How do we model personal features?

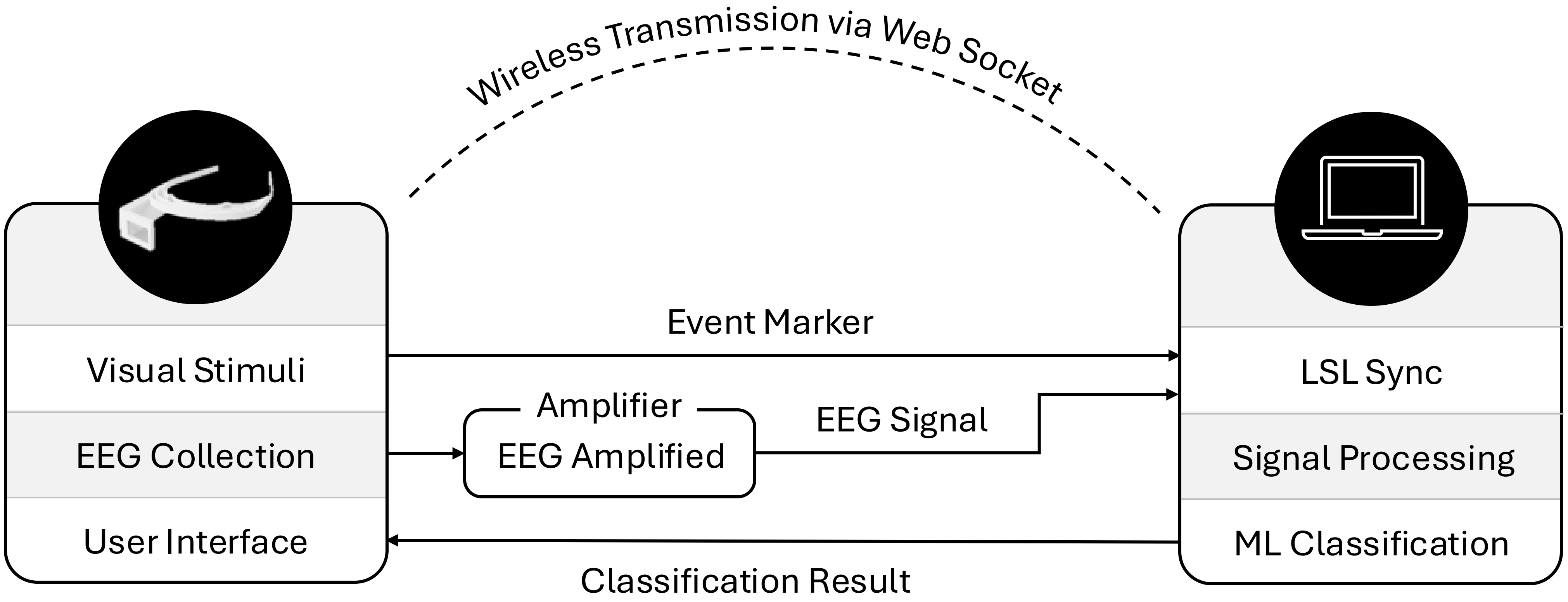
SSVEP Signal

Both the fundamental frequency (8 Hz) and the second harmonic (16 Hz) peak were observed during the stimulation state.



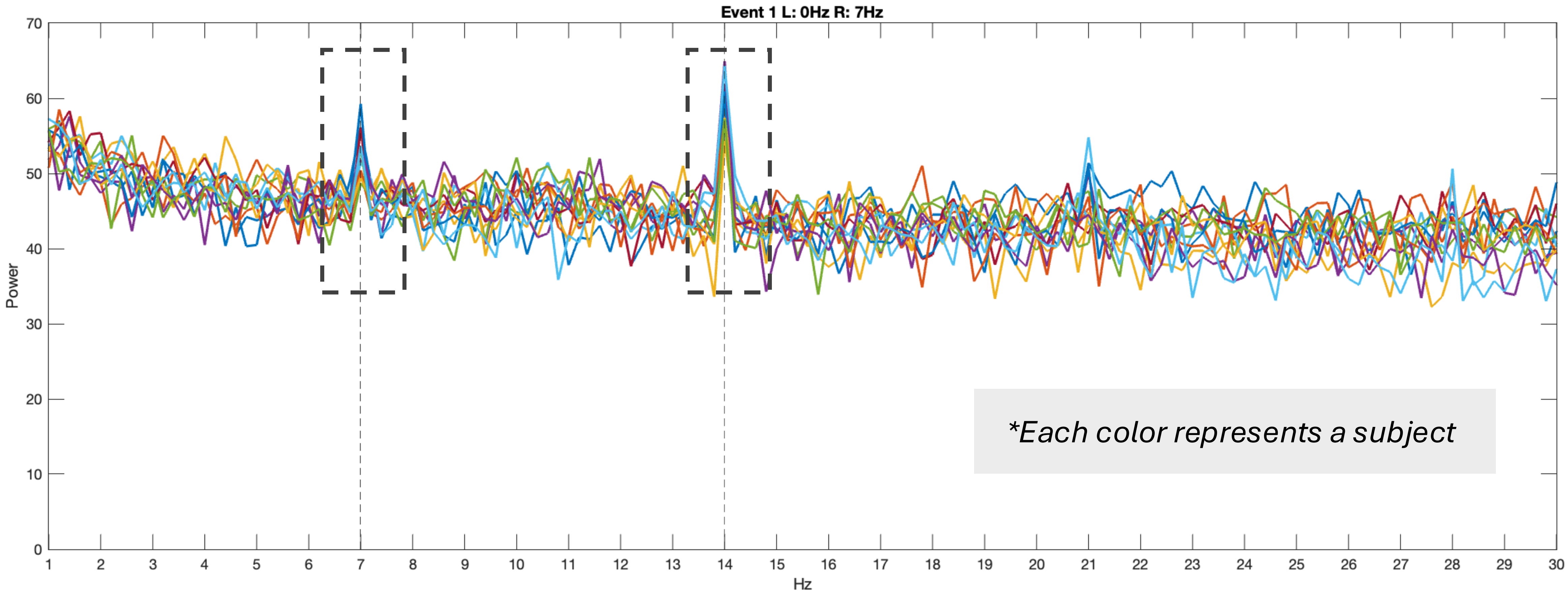
Data Flow and Communication

The device provides a WiFi wireless networking function, which can transmit data to the computer for computation through the wireless network connection and send the computation results back to the device.



Person Identification Goal

Capture individual differences through EEG (SSVEP) signals



Machine Learning Classification Result

We tested ML on personal identification using an existing dataset (Y. Sun et al., 2024).

- Decision tree model (DT): FPR **1.73%**, FNR **16.15%**
- Random forest model (RF): FPR **1.28%**, FNR **13.85%**

DT

Actual \ Predicted	Non-subject	Subject
Non-subject	1533	27
Subject	21	109

RF

Actual \ Predicted	Non-subject	Subject
Non-subject	1540	20
Subject	18	112

$$\mathrm{FPR} = \frac{\text{Logged in}}{\text{Non-subject}}$$

$$\mathrm{FNR} = \frac{\text{Rejected}}{\text{Registered subject}}$$