

# A Comparison of Alpha Rhythm Detection by Tripolar Concentric Ring Electrodes and Conventional Disk EEG Electrodes

Presenter(s): Chase Haddix<sup>1</sup>, Amir Al-Bakri<sup>1</sup>, Walt Besio<sup>2</sup>, Sridhar Sunderam<sup>1</sup>

<sup>1</sup>Department of Biomedical Engineering, University of Kentucky, Lexington, KY

<sup>2</sup>Department of Electrical, Computer and Biomedical Engineering, University of Rhode Island, Providence, Rhode Island

Results

#### Introduction

Electroencephalography (EEG) is commonly used in the clinical evaluation of brain health but the technology has remained unchanged for nearly 100 years. This measurement captures rhythmic firing from large neuronal populations from the scalp. While this approach is non-invasive, inexpensive, and relatively easy to use, there is a tradeoff in spatial resolution. Despite tremendous technological advances in neurology over the last century, little has changed to the core design of the EEG electrodes.

University of Rhode Island have records electrical potential with respect to a reference (Fig. 1) Potentials at these concentric combined approximate a focal Laplacian measurement with high spatial selectivity and reduced muscle artifact. Equation 1 is used for calculated the surface Laplacian estimate where  $V_o$  is the voltage  $\Delta p_0 \cong 16 (V_m - V_d) - (V_o - V_d)$  (1) on the outer ring,  $V_m$  is the voltage on the middle ring, and  $V_d$  is the voltage on the disc [1].



Figure 1. Comparison of Electrodes. Conventional gold cup electrode (left) and tri-polar concentric ring electrode (right).

$$\Delta p_0 \cong 16 (V_m - V_d) - (V_o - V_d)$$
 (1)

To benchmark performance of this tripolar EEG (tEEG) system, we measured the extent to which the alpha rhythm—an 8-13 Hz oscillation found in the EEG when the subject's eyes are closed—is modulated by opening the eyes in simultaneous tEEG and EEG recordings. Alpha activity becomes dominant during an eyes-closed condition compared to an eyesopen resting condition [2].

### Methods

Our preliminary study comprised seven healthy human subjects. A total of ten independent sessions were conducted in which subjects open and closed the eyes five times for 30s at a time.

EEG was recorded from frontal (F3, Fz, F4), central (C3, Cz, C4), and occipital (PO7, POz, PO8) channel locations (Figure 2). Tripolar leads were used to record EEG. Signal from the outer ring, which has been shown to emulate signal from conventional gold cup electrode, was recorded from each lead (EEG) and compared to the Laplacian estimate that incorporates both rings and center disk (tEEG). Therefore, two channels are recorded from each tripolar lead Potentials were digitized at 256 Hertz using g.Hlamp biosignal amplifier. (g.tec, Austria) and offline band pass filtered 0.1-100 Hertz. A global reference electrode was placed on the right mastoid and a grounding electrode was placed on the left mastoid.

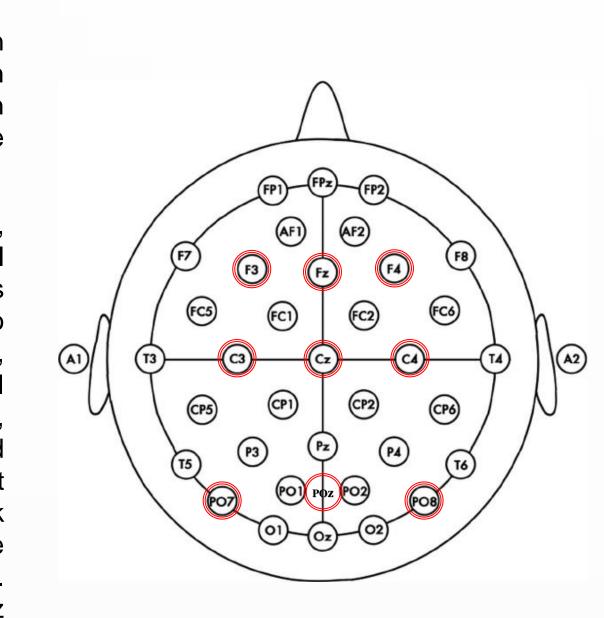


Figure 2. EEG scalp montage. Electrodes were placed in three rows – frontal, central, and occipital

To evaluate the performance of the tEEG system against conventional EEG recording, signal analysis was performed in both time and frequency domains. The blue tracings of Figure 3 show the signal recorded from an electrode located at PO7 from tEEG (top) and EEG (bottom) from a representative session. These signals were filtered 0.5 - 35 Hz to remove any high-frequency noise. This contrast is noticeably greater in the tEEG plot.

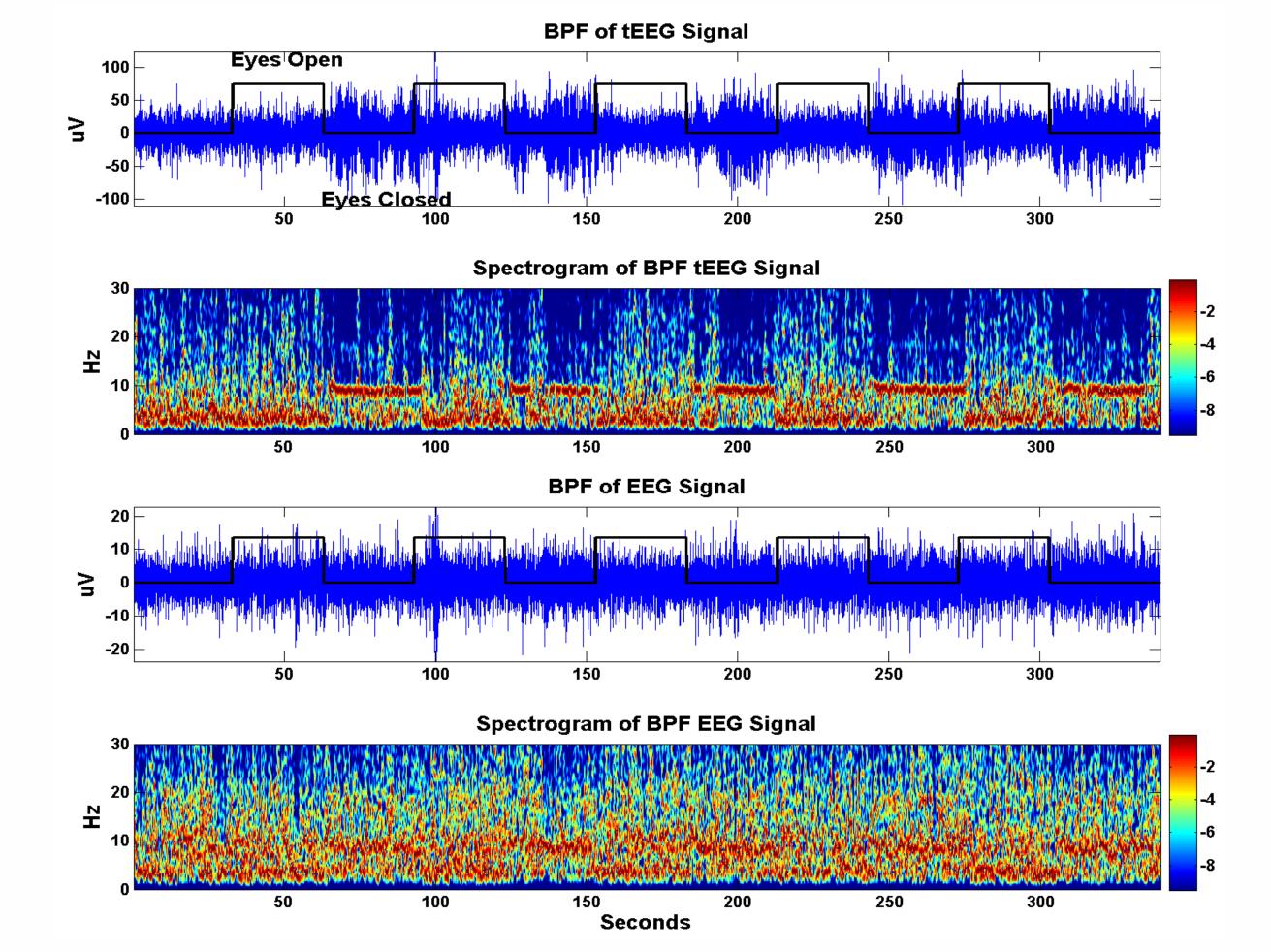
To better illustrate the signal differences, a six-second segment is shown for both tEEG and EEG (Figure 3, Right) during a transition from eyes closed to eyes open. The tEEG signal during eyes closed is visually more rhythmic and this is confirmed by computing the power spectral density estimate for the eyes closed (magenta) and eyes open (green) segments.

The difference in mean band power between eyes open and eyes closed was computed and normalized for each session (Eq. 2).

$$\frac{Bandpower_{\alpha,eyes\ closed} - Bandpower_{\alpha,eyes\ open}}{Bandpower_{\alpha,eyes\ closed}} \tag{2}$$

Next, the difference was found in alpha band power modulation between the two recording signals at each electrode location. Given the small cohort, a Wilcoxon signed-rank test was used. Results from pooled occipital channels show the difference is statistically significant (p = 0.0137) and a signed-rank of 51 out of 65 (n = 10) SEE FIG 4. This indicates the normalized difference in band power between eyes closed and eyes open is greater when recorded from the tEEG system. Figure 4 shows a measure of normalized alpha modulation computed independently for tEEG and EEG for all channels as well as the difference between the two (Diff).

## Alpha Modulation During Eyes Open/Closed



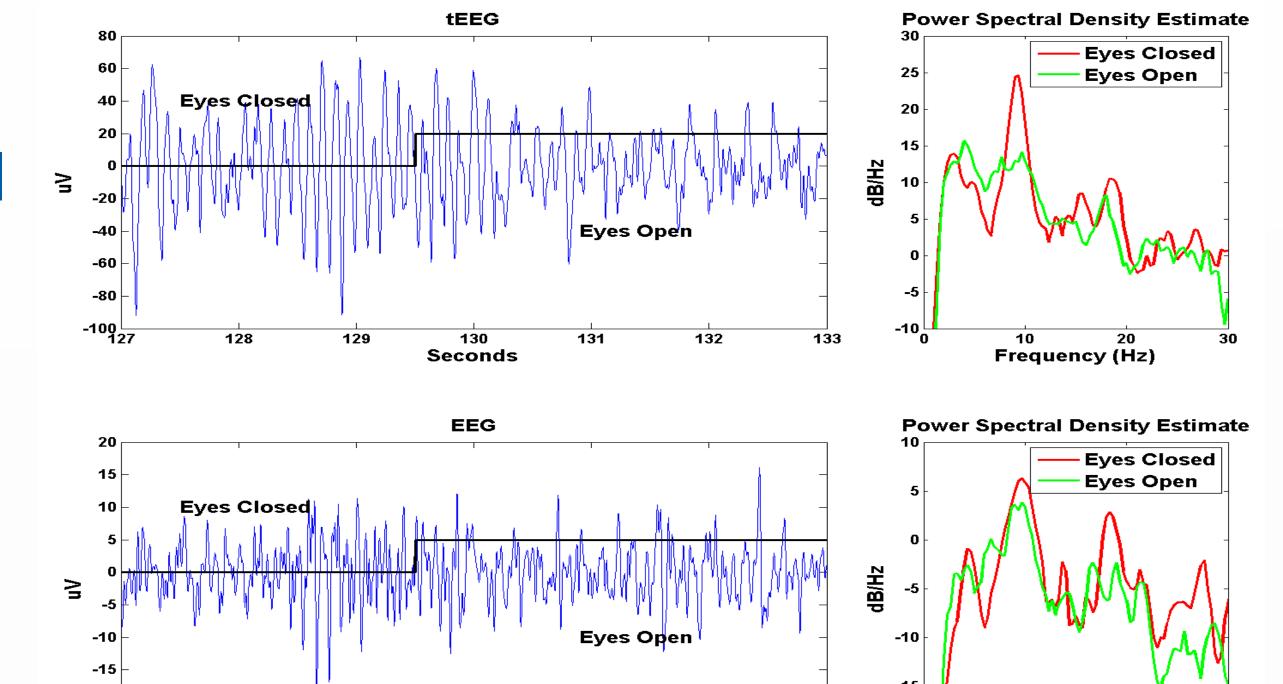


Figure 3. Temporal and spectral analysis of referential tEEG and EEG (outer ring) recording from channel PO7. Left: Band pass filtered (0.5-35 Hz) and normalized spectrogram of tEEG (top) and EEG (bottom). Right: Five-second segment during eyes closed tEEG and EEG and power spectral density estimate for the segment.

133

Frequency (Hz)

128

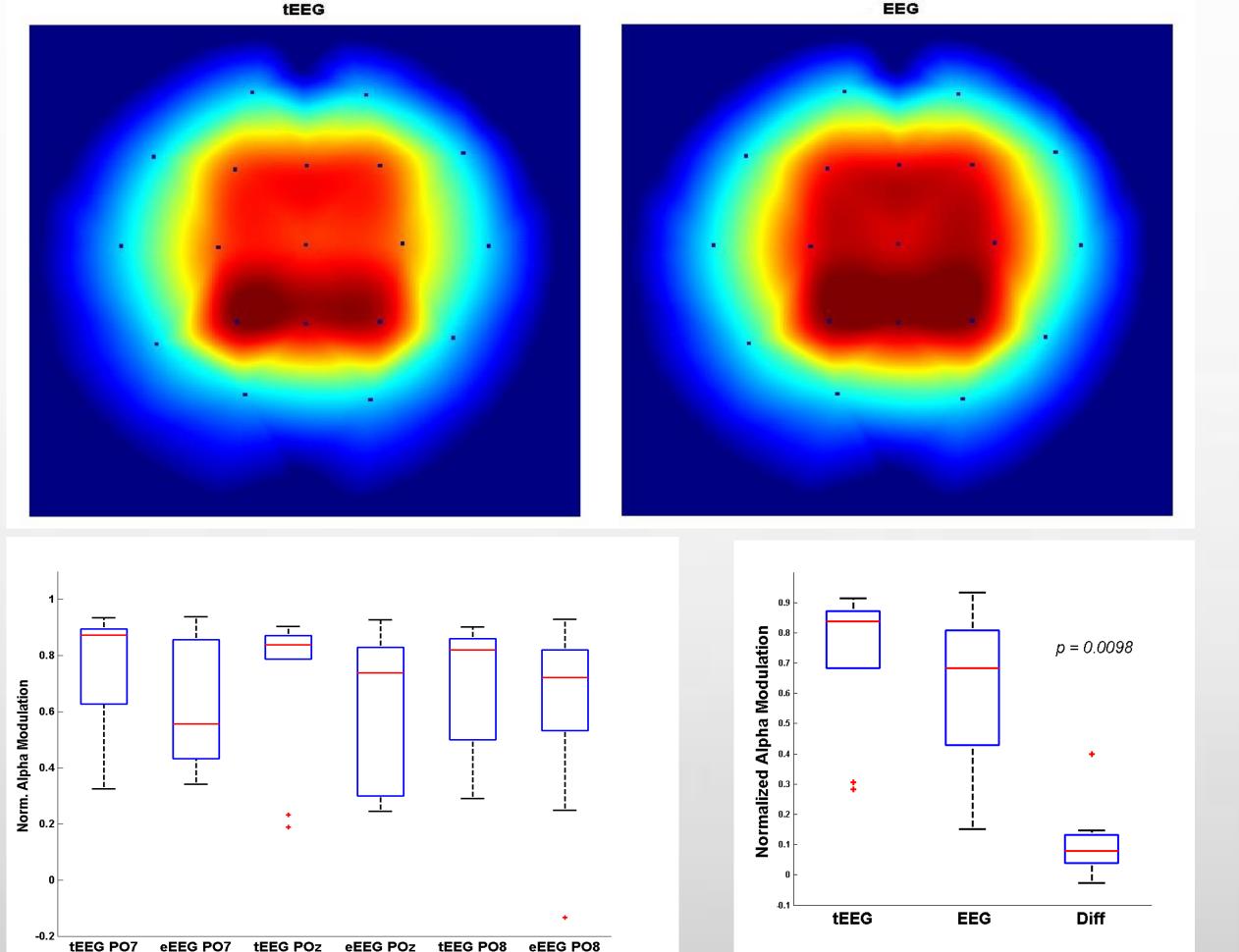


Figure 4. The heat map shows tEEG does a better job at isolating alpha activity to the posterior. The left boxplot shows that all posterior/occipital channels are good in tEEG compared to EEG – because the heat map might indicate a really strong modulation in the posterior for the EEG. The right boxplot is all 3 occipital channels averaged. Data for all three of these figures is from 10

# **Comparison of tEEG and Alternative Referencing Methods**

The TCRE system was then compared to re-referencing techniques commonly used in research and clinical settings from the EEG signal. The bipolar arrangement (Figure 5, left) took the difference between signals recorded from the outer ring of adjacent electrodes (PO7-C3, POz-Cz, PO8-C4). Common average referencing (CAR) measures the potential at a certain electrode with respect to the average potential across all electrodes. This showed similar results to the tEEG (figure 5, right).

All paired combinations of electrodes were tested and the optimal bipolar pairing for occipital channel alpha modulation was found. This represents the ideal case for the bipolar arrangement. The difference in alpha modulation between tEEG and re-referenced channels was not statistically significant.

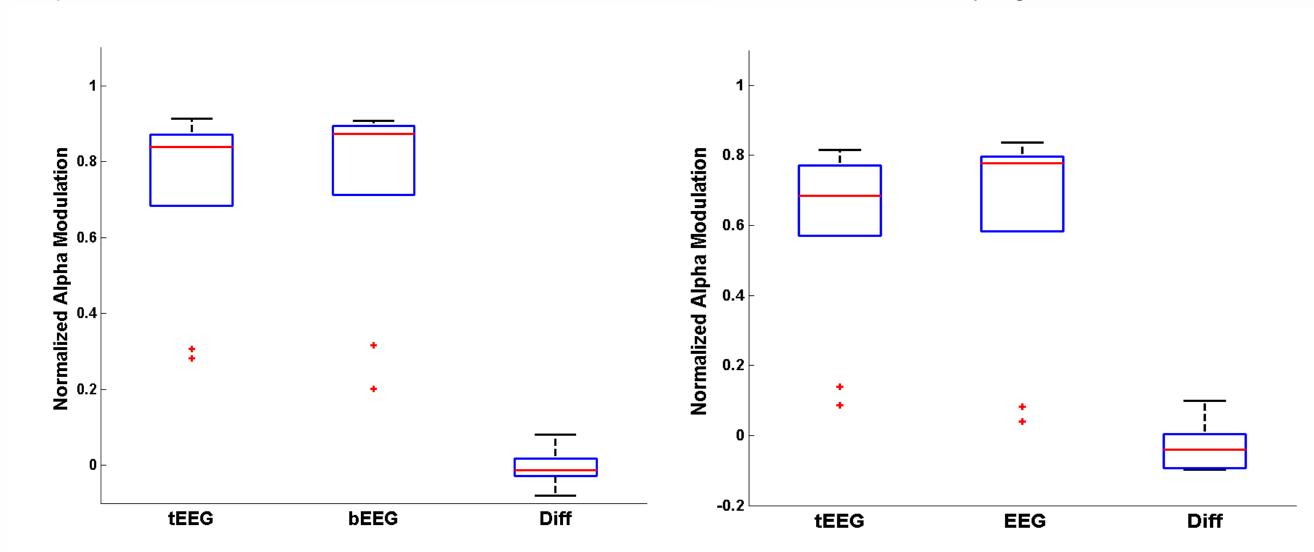


Figure 5. Comparisons of tEEG alpha modulation against bipolar (left) and CAR (right). The distributions indicate a similar performance in capturing alpha modulation. Bipolar arrangement is mapped anterior to posterior between occipital and central electrodes.

Table 1 Ontimal electrode pairing across all sessions

C3

10

P08

Table 1. Optimal electrode pairing across all sessions.				
SID	P07	POz	P08	0.02
1	Fz	Cz	C4	
2	Fz	Cz	Cz	Difference in Normalized Alpha Modulation -0.06 -0.08 -0.12 -0.12
3	Cz	P07	POz	o.ualized -0.06
4	C3	C4	P07	-0.1 - U.1 - 0.12 - U.12 - U.1
5	C3	C4	POz	-0.14 -0.14
6	F3	C4	C4	tEEG - Optimal Bipolar EEG  Figure 6. Difference between tEEG and optimal EEG for all
7	F3	F3	C4	sessions. In this optimal case, where bipolar referencing between occipital electrodes and another electrode producing the greatest alpha modulation, tEEG is only slightly worse.
8	Poz	Fz	C4	
9	C3	Cz	C4	

## **Conclusions and Future Directions**

P07

These preliminary results suggest using the tripolar EEG system may better detect changes in brain activity. In this study, modulation was confirmed in both tEEG and EEG recordings in the alpha and sensorimotor rhythm. In a referential recording, the tEEG system captured change in alpha rhythm better than conventional EEG during an eyes open/closed task in 8 of the 10 sessions (p = 0.0137).

The TCRE sensors estimate the surface Laplacian directly. A comparison of this technique against bipolar and common average referencing did not show a significant difference in terms of alpha modulation. The TCRE sensors have a radius approximately equal to standard passive electrodes. Therefore, the effects of volume conduction are much less for tEEG recording than a between-electrodes bipolar recording. Furthermore, bipolar and common average referencing require multiple electrodes, with the location of the referenced electrode being critical to the output signal. The tEEG electrodes only need a global reference and ground.

Future efforts will be made to increase the number of recorded sessions and extract more features that may give greater insight into the ability of the tEEG system to capture localized brain activity. These earlier results indicate the novel tEEG system may show promise in other areas of EEG research including sleep scoring and movement intention.

## Acknowledgments

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## References

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