

Linear Synchrony to Emulate Disc Electrode with Middle Ring or Central Disc of a Concentric Ring One

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Some noninvasive electrophysiological measurement applications benefit from simultaneous collection of data via both conventional disc electrodes and via tripolar concentric ring electrodes (TCREs), so an emulation of the former by the outer ring of the latter was previously proposed and since adopted widely. Its effectiveness was validated using linear time and frequency domain signal synchrony measures (cross-correlation and coherence respectively). This approach represents an alternative to recording from both electrode modalities concurrently, which may involve two recording systems and potential synchronization issues with signals not recorded at exact same locations.

However, recent application of a nonlinear signal synchrony measure, normalized mutual information, resulted in mean values of less than 0.7 between outer ring of a TCRE and the disc electrode on both phantom model and human electroencephalogram (EEG) datasets [1], indicating that the outer ring of a TCRE may not be as suitable as an emulation of the disc electrode as previously suggested. Therefore, in this study, alternative options such as middle ring and central disc of a TCRE were assessed on the resting EEG data from six human subjects from [1]. Central disc and middle ring channels were not recorded directly in this dataset, and were obtained through subtraction and addition of other monopolar and bipolar channels (e.g. subtraction of the outer ring monopolar channel and the bipolar channel corresponding to the outer ring minus the central disc allowed assessing the data corresponding to the central disc) with all resulting channels normalized to zero mean and unit standard deviation. The same two linear signal synchrony measures were used.

Average cross-correlation values for middle ring and central disc versus disc electrode were 0.984 ± 0.012 and 0.986 ± 0.01 , respectively. Average coherence values for middle ring and central disc versus disc electrode were 0.969 ± 0.0245 and 0.979 ± 0.0164 , respectively. These are comparable to previously obtained outer ring values: average cross-correlation of 0.9905 ± 0.0065 and average coherence of 0.9818 ± 0.0133 on the same human EEG dataset. For both time- and frequency-domain measures, this comparison shows that middle ring and central disc are lower than outer ring but the difference is small enough to provide viable alternative emulation options if needed. Research significance of this study stems from assessing central disc and middle ring as emulations of disc electrode using linear synchrony measures for the very first time.

- [1] S. Chee, A. Benally, O. Makeyev, Y. Ye-Lin, G. Prats-Boluda, and J. Garcia-Casado, "Normalized Mutual Information in Phantom Model and Human Electroencephalogram Data for Emulation of Conventional Disc Electrode via the Outer Ring of Tripolar Concentric Ring Electrode," in *2025 IEEE 22nd International Symposium on Biomedical Imaging (ISBI)*, Apr. 2025, pp. 1–4. doi: 10.1109/ISBI60581.2025.10980659.