Neuronal activity is composed of synchronous and asynchronous oscillatory activity at different frequencies. The neuronal oscillations occur at time scales well matched to the temporal resolution of electroencephalography (EEG); however, to derive meaning from the electrical brain activity as measured from the scalp, it is useful to decompose the EEG signal in space and time. In this study, we elaborate on the investigations into source-based signal decomposition of EEG. Using source localization, the electrical brain signal is spatially unmixed and the neuronal dynamics from a region of interest are analyzed using empirical mode decomposition (EMD), a technique aimed at detecting periodic signals. We demonstrate, first in simulations, that the EMD is more accurate when applied to the spatially unmixed signal compared to the scalp-level signal. Furthermore, on EEG data recorded simultaneously with transcranial magnetic stimulation (TMS) over the hand area of the primary motor cortex, we observe a link between the peak to peak amplitude of the motor-evoked potential (MEP) and the phase of the decomposed localized electrical activity before TMS onset. The results thus encourage combination of source localization and EMD in the pursuit of further insight into the mechanisms of the brain with respect to the phase and frequency of the electrical oscillations and their cortical origin.