The Voltage Divider Effect

What is the voltage divider effect?

The voltage divider effect is an interaction between the (tip) impedance of a microelectrode and the input impedance of the headset amplifier. Under certain conditions, this effect can lead to amplitude attenuation and phase shifts between the true signal and the signal observed by the acquisition system.

In general, this effect becomes significant when the electrode impedance is comparable to or greater than the input impedance of the headset amplifier being used. For example, as long as the input impedance of the headset amplifier is 10x the impedance of the electrode, then the phase shift due to the voltage divider effect will not exceed 6° and the observed signal will not be less than 90% of the amplitude of the true signal. Furthermore, this maximal phase shift effect and maximal amplitude effect can not occur simultaneously.

When does this effect occur?

The impedance of micro-electrodes is commonly measured at a frequency of 1 kHz. However, the impedance of a typical microelectrode increases dramatically at lower frequencies. Thus an electrode that has an impedance of 1 MΩ at 1 kHz may have an impedance of 20 to 30 MΩ at 10 Hz (Figure 1). For some electrodes, the increase can be even more dramatic with the impedance increasing by nearly a factor of ten for each ten fold decrease in the frequency. Thus even an electrode that is 300 kΩ at 1 kHz may approach 300 MΩ at 1 Hz.

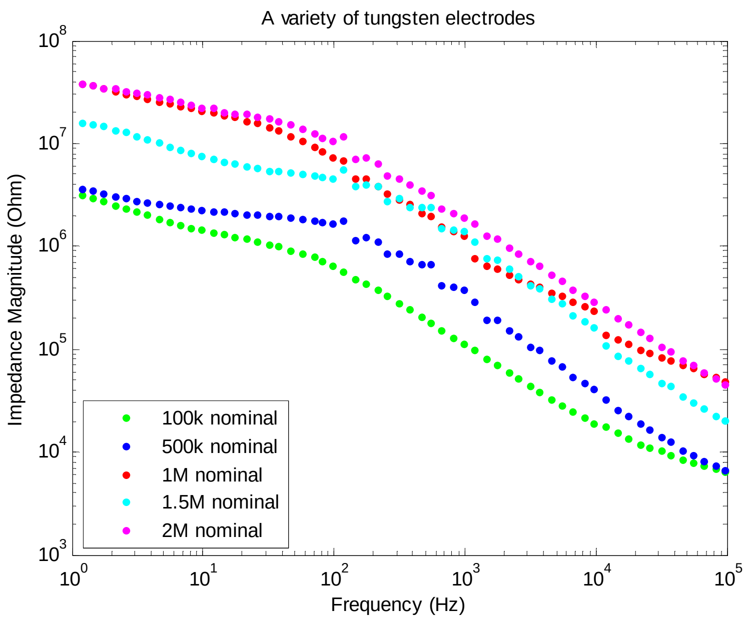


Figure 1

The same is usually true of headset input impedances; the input impedance tends to increase as frequency decreases. However, one particular headset amplifier, the HST/8o50-G20 (Rev 3.0) has AC coupling circuitry to block the electrochemical offset potential of the electrode in saline. Unfortunately, the particular implementation of this circuitry also limits the input impedance of the headset to around 47 MΩ from 1 Hz to 200 Hz. (Figure 2)

The Voltage Divider Effect

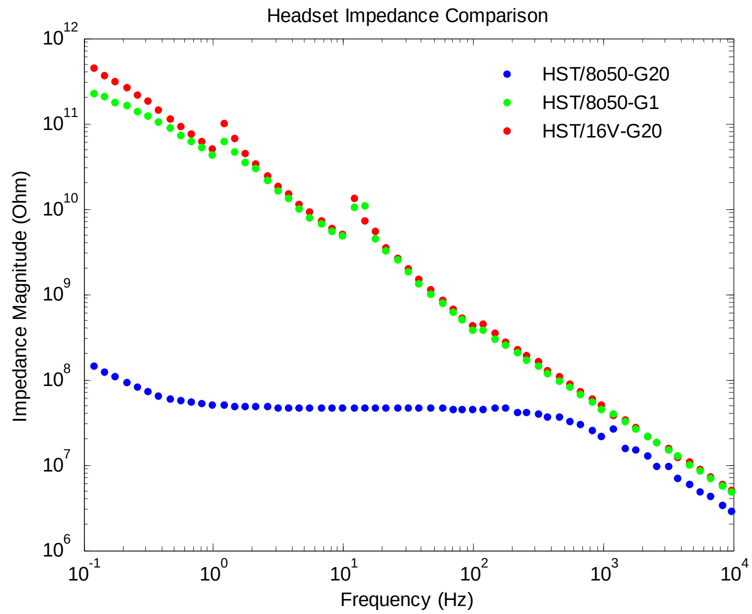
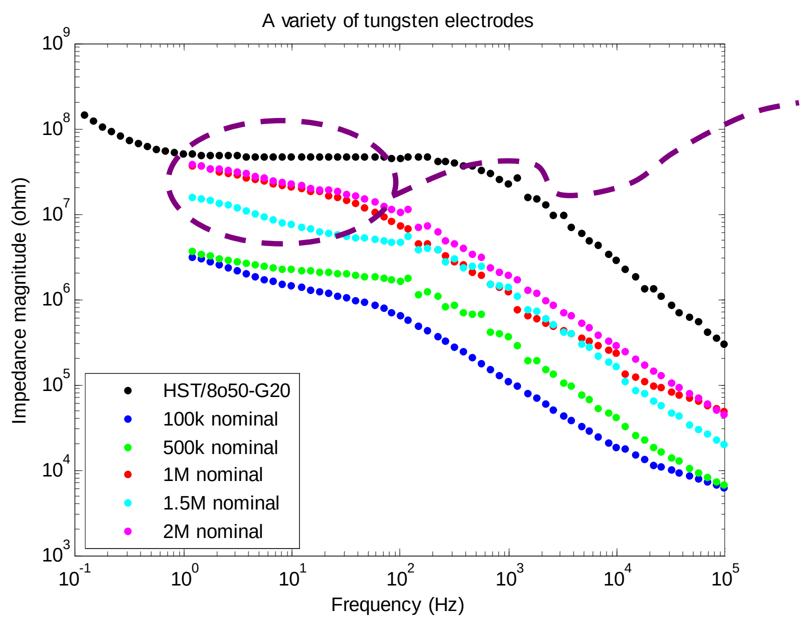


Figure 2

This plateau in the input impedance spectrum of the HST/8o50-G20 (Rev 3.0) headset combined with the increasing impedance of the microelectrode at low frequencies means that the impedance of the microelectrode can approach or even exceed the input impedance of the HST/8o50-G20 (Rev 3.0) headset at low frequencies. (Figure 3) Under these conditions, the voltage divider effect can occur and the observed signal can be attenuated and phase shifted relative to the true signal. See the links below for examples of the voltage divider effect between the HST/8o50-G20 (Rev 3.0) headset and a variety of different electrodes.

The HST/8o50-G1 and HST/16V-G20 headsets do not exhibit this input impedance plateau and thus do not exhibit a significant voltage divider effect with typical electrodes.



The magnitude of the electrode impedance (red, pink, blue) is approaching the magnitude of the HST/8o50-G20 headset input impedance. The voltage divider effect can occur.

Figure 3

The Voltage Divider Effect

Where can I go for more information?

1. For a basic theoretical introduction to the voltage divider effect, information on how to calculate it, and some basic examples see:
Introduction_to_the_voltage_divider_effect.pdf

2. For the impedance spectra of a variety of electrodes and headset amplifiers and an analysis of the voltage divider effect that would occur when these are used together see:
Electrode_impedance_and_voltage_divider_effect_gallery.pdf

3. For data on the nominal input impedance of the HST/8o50-G20 headset see:
HST-8o50-G20_input_Z.pdf

4. For a published discussion and analysis of this effect see:
Nelson MJ, Pouget P, Nilsen EA, Patten CD, and Schall JD. (2008) Review of signal distortion through metal microelectrode recording circuits and filters. Journal of Neuroscience Methods 169: 141-57.