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Noise and Interference in Deuteron's Wireless Neural Recorders

This note compares the relative levels of signal and noise, expected and measured, using Deuteron's wireless neural recorders.

The noise level that is observed in a neural recording is the combination of the following:

- Johnson noise due to the effective impedance of the electrodes
- The noise level of the preamplifier
- Artifacts, if any, that are generated by the recording system
- Non-neural signals made by the animal, for example by strong muscular movements
- Environmental electronic noise picked up by electrodes and their wires
- Background neural noise.

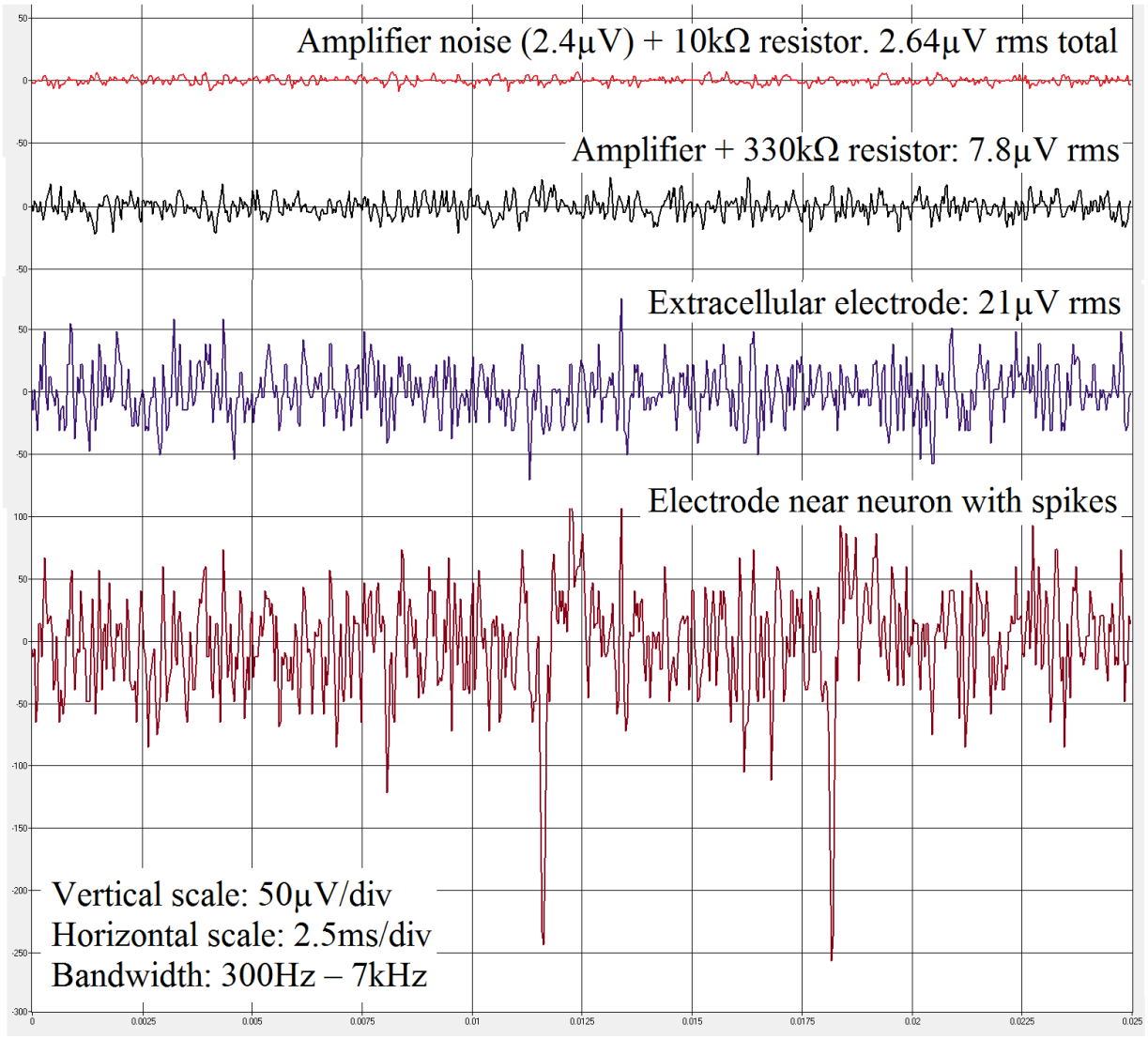
Johnson noise is the thermal noise exists in any device that has electrical resistance, and is given by the formula $V_{Jn} = \sqrt{4kTRB}$, where k is Boltzmann's constant, T is the absolute temperature, R is the electrical resistance, and B is the bandwidth of the measurement. A 500kΩ resistor generates 7.6μV rms of Johnson noise when measured with a 7kHz bandwidth. Since it is generally impractical to reduce the electrode impedance or the temperature, one must often accept Johnson noise as the inevitable minimum noise in a system. One must ensure that all interference and noise in electrophysiology equipment is insignificant compared to this.

The electrical noise of the preamplifiers of all Deuteron's neural recorders is about 2.4μV rms when measured with a 7kHz bandwidth. The total (root of sum of squares) of preamplifier noise and Johnson noise from a 500kΩ source is 8.0μV rms, which is almost entirely due to the Johnson noise.

The amount of environmental electrical interference that will be picked up depends on how noisy the environment is, the quality of the electrical shielding, and on the length of the wires between the electrode tip and the preamplifier. On Deuteron's recording devices, the distance between the input connector and the preamplifier is always less than 1cm, most of which is shielded. When designing electrode assemblies, it is important to keep the length of wires between the electrodes and the connectors as short as practical. An important feature of any wireless neural recording system is that with no conductive connection to ground, a wireless device has a large inherent immunity to picking up electrical interference, particularly at the line frequency (50/60Hz). Therefore, in normal laboratory conditions where the electrode wires are short, there is no need for any special electrical shielding when recording wirelessly.

Measurements

The waveforms shown in the figure below show measured signal and noise levels using one of Deuteron's wireless recorders. The four waveforms are all shown to the same scale and were all recorded in an unshielded environment with analog filters that limit the signals to the frequency band from 300Hz to 7kHz.



The uppermost waveform was measured when the neural recorder was connected to a 10kΩ resistor instead of the electrode assembly. The measured signal essentially represents the input noise of the preamplifier. The observed 2.64µV rms noise is due to the 2.4µV rms noise of the preamplifier and the uncorrelated 1.07µV rms Johnson noise of the 10KΩ resistor.

The second trace similarly shows the signal recorded from a 330kΩ resistor. Because the source impedance is much higher, the recording is now dominated by Johnson noise. The measured noise was 7.8µV rms; the Johnson noise expected from a 330kΩ resistor is 6.1µV rms.

The next two traces were recorded simultaneously using 500kΩ-impedance electrodes close to each other in the brain of a freely moving mammal. One of these electrodes picked up neural spikes while the other one did not. Note that the 21µV measured neural background noise is significantly greater than the electrode's Johnson noise. One can thus be confidant that no significant component of the noise that surrounds the spikes seen in the fourth waveform is the result of preamplifier noise or any other electronic artifact.

Conclusion

The measured amplifier noise of the neural recorder is very small compared to a typical electrode's Johnson noise, and the Johnson noise of a typical electrode is small compared to typically observed background neural noise in living brain tissue. The wireless neural recorder recorded neural spikes with no observable artifacts or other electrical interference.