Neuralynx ~ TechTips

Noise Debug 101 - Introduction

Noise is any unwanted signal that contaminates your desired signal. It may originate internally from other bioelectric signals or externally from any voltage or magnetic energy source. There are many external noise sources from our high-tech world, many of which are generated by necessary technology such as computers and AC wall power. The challenge for neuroscience researchers is to find solutions that reduce or eliminate the noise source or reduce the coupling of the noise into the recording setup.

Magnitude of Signals

The challenge of noise in the electrophysiology environment is the magnitude of the desired signals from the brain (microvolts to millivolts) to the external noise sources (hundreds of volts) in the laboratory environment. This represents a “100 Million to One” ratio of desired signals to noise sources.

The good news is that noise signals can be greatly reduced or entirely eliminated through proper identification and coupling reduction techniques! Part 5 of this series will cover recording techniques used to eliminate noise signals on our electrophysiology data.

Key Electrical Engineering Concepts & Terms

1. A signal (current) always flows in a complete loop. It is important to keep the “loops” in mind when analyzing the source of the noise and how it is coupled into your recording circuit. The total voltage drop around a loop is always ZERO.
2. Whenever current flows through a conductor, there is a voltage drop because every conductor has resistance.
3. Ohm’s Law is key to this discussion: V = I * R Voltage drop = Current times Resistance.
4. Changing signals (AC signals other than static DC values) will be conducted by capacitance as well as by conductors; there is capacitance between any two metal objects anywhere in space. The higher the frequency of the noise, the better it will be conducted by capacitance.
5. A changing magnetic field will induce a voltage and current flow into a conductor, single wire or a loop of “turns.” The magnitude of the induced signal is based on the number of turns in the loop and the area of the loop.
6. Ground is not absolute! There is no such thing as a “perfect earth ground.” Ground is only a point where measured voltages are relative to: you can measure significant voltages between two different close locations in the earth.
7. Voltage drops in a circuit (loop) are based on the ratio of component impedances of each component.
8. Impedance and Resistance are very similar: Resistance is for “steady state” DC circuit analysis; and Impedance is for the AC frequency circuit analysis. Both are measured in Ohms, but impedance has an

"imaginary or complex component" resulting in a "phase shift."

9. The term "Ground Loop" is often misunderstood. When you have an "extra conduction path" around a circuit, it usually does not result in "magnetic coupling into the ground loop" creating current flows and AC power line frequency noise.

Noise "Sherlocking"

When you observe an external noise signal in your recordings, you must first identify the noise source. This is done by observing the signal and answering such questions as:

- Is it at the AC Power Line frequency or a multiple of the frequency?
- Is it dependent on location?
- Is it dependent on a piece of equipment being turned on or plugged in?
- Does you hear anything unique, like music, when listened to?

These will all provide you with clues about the source of the noise.

After you determine the noise source, you need to run some experiments to determine the external coupling type that is causing the noise to "get into your setup." For example, a florescent light has three possible conduction types: electrostatic from the high voltage (120 or 220VAC), magnetic from the turns of wire in the ballast; and RF from the high frequency "sharp edges" of the florescent tube starting and stopping current flow on every ½ cycle of the power line voltage cycles. Note: "Getting out the aluminum foil" for every noise problem usually doesn't work and the "fix" may be rather inconvenient.

Once you identify the source and coupling type, it is usually easy to implement a solution to resolve your noise problem, delivering clean, recorded signals!

Our **Noise Debug 101** series will examine the physics behind each coupling type and the method(s) for designing an experiment that test for its magnitude.

Parts 1-4 address the four main types of external (environment) noise signals:

- Part 1 - Conducted Noise (common path voltage drop)
- Part 2 - Electrostatically Coupled (voltage coupled)
- Part 3 - Magnetically Coupled
- Part 4 - Radio Frequency Coupled
- Part 5 - Practical Noise Abatement

RF Interference

Radio Frequency (RF) Interference occurs when a conductor is in the RF field of a transmitted radio source. Increasingly, wireless devices infiltrate our environment making the occurrence of RF interference more common. Cell phones operate at high frequencies (1 to 5Ghz which is hard to shield) and transmit up to 1 watt of signal. Often a cell phone call can be detected on microwire recordings before the phone rings!

Radio Frequency energy, or electromagnetic radiation, consists of coupled electric and magnetic fields. Therefore both the electrostatic and magnetic noise abatement techniques from the previous two Noise Debug 101 articles both apply.

For RF coupling to induce a significant amount of energy, the distance between the source (transmitter) and the desired signal (receiver) is usually greater than 4 to 10 wavelengths. Less than this distance, the coupling type will be electrostatic or electromagnetic and can be treated as such. Wavelength is the speed of light divided by the frequency, ($3*10^8$ / F). For example, a 1 MHz AM radio station has a wavelength of 300 meters, while a 4G phone has a wavelength of only 7.5cm.

When debugging RF noise, always use the audio output feature of Neuralynx's Cheetah and the Digital Lynx. We have heard classical music, talk radio, and campus security audio from the recording systems that are very hard to debug without using your ears. Cell phones may sound like "periodic noise patterns."

Solutions

Question: How is high frequency RF energy coupled into my low frequency signals?

Answer: All active electronic parts contain diodes and transistors. If the coupled RF signal is strong enough, it will be present at the first amplifier chip and be “rectified” by a diode or transistor inside the amplifier IC. (This is the principle of a “crystal radio” receiver.) Good amplifiers employ high frequency filters before the inputs to keep out RF signals.

Tests for RF Coupling

The first step is to listen to the noisy channel through Cheetah and the Digital Lynx. If you hear music or speech, listen for the radio station’s “call letters” on the hour and half hour. If cell phones are suspected, make a call and position it close to the subject’s headstage to maximize the noise.

RF Coupling Solutions

Many times the same solutions for electrostatic conduction will work for RF interference because RF is coupled electrical and magnetic fields.

The easiest solution is to remove the RF noise source (i.e., ban cell phones in the recording room). If this can't be done, as in the case of a radio station, try electrostatic and magnetic solutions. Try the "aluminum foil test" around the subject. We have seen a grounded copper-foil on the exterior of a microdrive work wonders.

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  Try a Faraday Cage around the animal although this may not be possible for large maze experiments.

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  Ground unused inputs on a headstage. This effectively removes the "open antenna" from picking up the RF signal.

If you have unshielded tethers, such as on the Neuralynx HS-8 or HS-18 Cooner, switch to a shielded tether cable model.