The Risks of Using Unshielded Cables

Introduction

Cell cables are an integral part of your potentiostat and can have a large effect on full measurement capabilities of the complete system. They provide connection between the potentiostat itself and your electrochemical cell. Gamry Instruments' cables are specially designed and manufactured to minimize and eliminate noise from infiltrating the measurement. These cell cables have a reproducible shielding added to reduce external electrical noise from other electrical apparatus nearby, as well as inductance from other nearby cell cables.

Many times we see customers adding excess cables to the ends of the cell cable without understanding the possible side effects of this action. This Technical Note will show why adding extra unshielded cables can cause significant noise and distortion to your data.

When Can Lack of Shielding Become a Serious Problem?

For more information about overall system limitations, see our "Low-impedance EIS at its Limits: Gamry Reference 30k Booster Application" and "Accuracy Contour Plots" notes. This Technical Note deals with just the cell cables themselves.

The cell current flowing through the cables connecting the instrument to the cell generates a magnetic field that can be picked up in the voltage sensing leads. This effect, called mutual inductance, is a function of frequency. Mutual-inductance error is generally insignificant at low frequency, and totally dominates the measurement at high frequency. The impedance error from mutual inductance generally models as an apparent inductance in series with the "true" cell impedance. Moving the cell leads changes mutual-inductance errors.

External changing magnetic and electrical fields, such as produced by motorized equipment, cooling fans inside computers, and even the power line (mains) can severely affect all local wiring, including your cables connected between a potentiostat and cell. The cables act as antennas, inducing a changing voltage and current within your test circuitry.

Mutual inductance generally becomes more of a problem when running AC measurements, such as electrochemical impedance spectroscopy (EIS). DC measurements are much less affected by external changing magnetic and electrical fields such as motors inside other scientific apparatus and computers.

The Solution

Essentially we use a miniature Faraday cage around the conductor. That is, braided shielding encircles each cable. We also calibrate each instrument to the cell cables supplied with it, and we allow you to redo this calibration as necessary.

…But Then You Add Unshielded Cables…

Adding unshielded cables with alligator clips may make the connection between a potentiostat and a test sample or electrochemical cell more convenient. The extra cables, though, revert to antenna pick-ups for motor-caused and inductive fields traversing through the laboratory. Below we show an actual example.

We used our Interface™ 1010 potentiostat with our standard shielded 60 cm cell cables and extra unshielded 1 m cables. The test subject was a 5 F supercapacitor run in a galvanostatic electrochemical impedance spectroscopy (EIS) experiment. (See Fig. 1.) Results are given in Figure 2.

Notice the striking difference between the unshielded EIS (red) and the shielded (blue). A distortion like this based on local electromagnetic fields can play havoc with your data and analysis. The added cables have the effect of increasing mutual inductance—as mentioned earlier—but they also reduce the effective bandwidth of

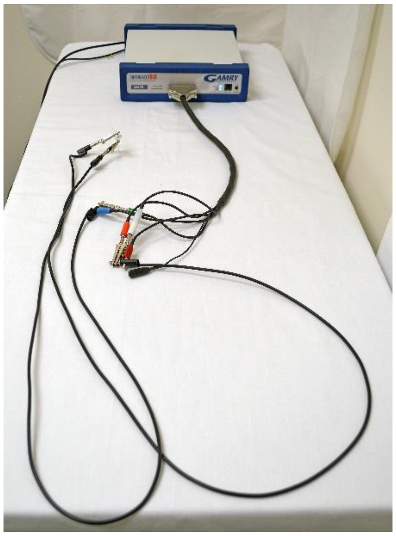

Figure 1. Potentiostat with standard cell cables plus unshielded cables, connected to a supercapacitor.

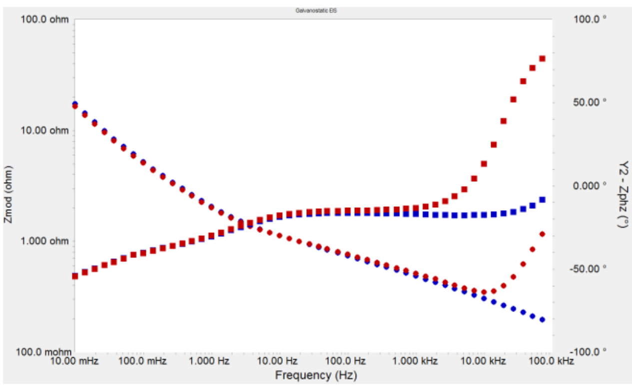

Figure 2. EIS comparison of 5 F supercapacitor with (blue) standard Gamry Instruments shielded cell cable versus (red) standard cell cable plus 1 m unshielded extensions.

your measurement. Notice the large phase-shift from the higher frequencies until down to below 1 kHz.

Next we added a Julabo® F25 temperature bath with its circulator and heater operating, to provide a source of ambient electronic noise near a test system with and without unshielded extension cell cables. Figure 3 illustrates the obvious difference between the two cases. Here, not only has the mutual inductance increased, reducing your effective bandwidth, but the overall impedance shows differences until low frequencies.

What kind of noise are we seeing?

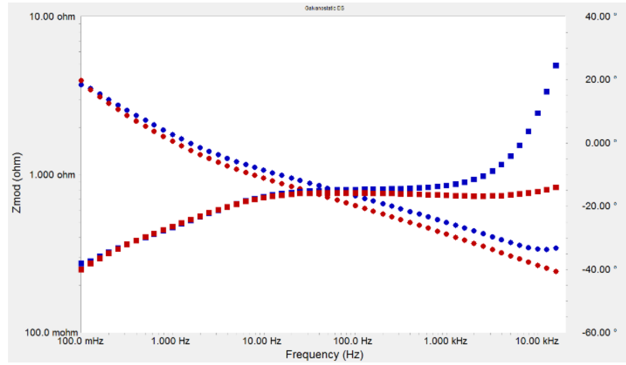

Figure 3. EIS similar to Figure 2, except that the shielded (red) and unshielded (blue) cables are near an operating source of electromagnetic noise.

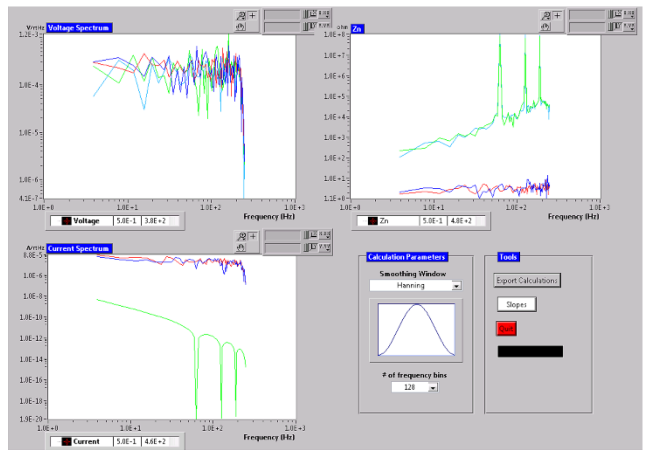

Figure 4. Fourier analysis of four different experimental conditions: Blue, shielded cables and no motor; red, shielded cables with motor; light blue, unshielded cables and no motor; green, unshielded cables with motor. Top left is the voltage PSD, bottom left is current PSD, and top right is impedance PSD.

We ran Gamry Instruments ESA410 software to capture the real-time current and voltage signals and perform a Fourier power spectrum analysis (PSD), while connected to a 2 kΩ Gamry Instruments Calibration Cell. A comparison of shielded and unshielded cables with and without external motorized equipment is given in Figure 4.

The most obvious difference to be observed is the presence of 60 Hz (power-line) interference, plus second-harmonic (120 Hz) and third-harmonic (180 Hz) noise in the unshielded cables while the temperature bath was operating. Not only that, the general noise level increases when unshielded cables are used even if no nearby motor is running.

Summary

This Technical Note shows that for many applications of electrochemical testing, shielded cables are a must. We do not recommend extending your standard cell cables. Instead, use longer shielded cables or contact us for customized cables.

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