

Cable-capacitance Correction

What is it? Why do we care?

The individual conductors in the cell cable of the potentiostat are made up of coaxial cables. The outer conductor in a coaxial cable is used to shield the signal of interest. Cable capacitance arises in coaxial cables because of the insulation between the wires. It takes a certain amount of time for the cable to reach its charged level. This lag in charging time slows down the signal being transmitted, and even interferes with that signal. This effect is particularly pronounced for high-frequency signals like those that occur in Electrochemical Impedance Spectroscopy (EIS) measurements.

If we consider the example of digital data pulses represented by a square wave with near-vertical rises and falls entering one end of a coaxial cable, a cable with a high capacitance slows these voltage transitions so that they come out of the cable's opposite end looking more like saw-teeth (see Fig. 1). The end result is a distortion of the signal—and your data.

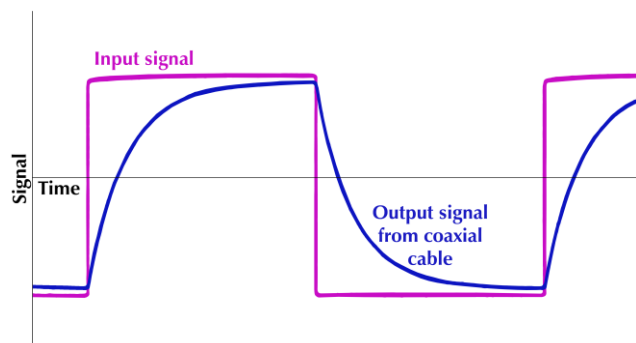


Figure 1. Example of what happens to the signal when a square wave (purple) is passed through a coaxial cable (blue).

Controlling Cable Capacitance

A lot of research goes into minimizing the cable capacitance. Some ways to accomplish this include increasing the wall thickness of the insulation, decreasing the conductor diameter, or using insulation

with a lower dielectric constant.

But another way to handle this problem is via software correction.

Results

Gamry Instruments incorporates two levels of correction for the cable capacitance into our software:

- The first is built into the software and is a correction when using a standard cable. This general correction removes 99% of the anomalies caused within the cable itself.
- The second level of correction removes the last 1% that occurs because of small differences between individual cables caused by the manufacturing process. The second level of correction can account for these small differences and yield more-accurate data.

For a first test of correction, results were generated using a Reference 600+™ Potentiostat with a 60 cm Reference 600™ cell cable. Data were acquired with and without cable-capacitance correction on a 10 nF capacitor. Figure 2 shows only the data with no correction for cable capacitance.

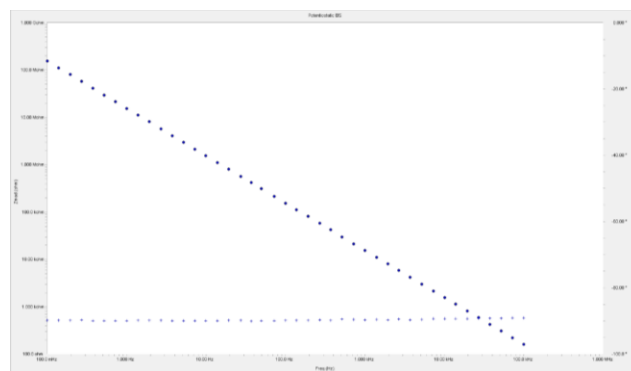


Figure 2. EIS of Gamry Instruments' calibration cell with no correction for cable capacitance, measuring a 10 nF capacitor. Note how linear the data are.

At this size of capacitor, cable capacitance is clearly not much of a problem. Phase-errors caused by range-switching in the potentiostat are generally less than 0.2° .

Shrinking the value of the test capacitor a couple of orders of magnitude, we tried EIS on a 470 pF capacitor (Figure 3).

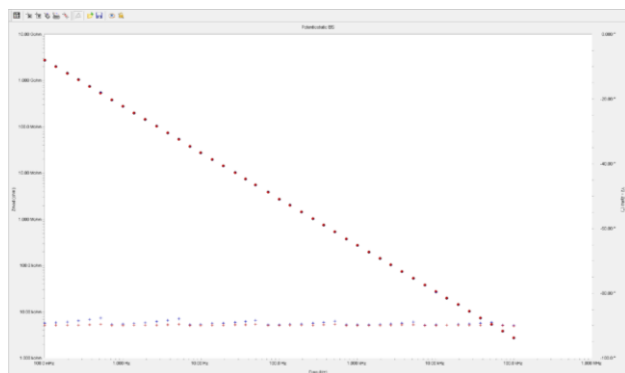


Figure 3. EIS of a 470 pF capacitor without (blue) and with (red) cable-capacitance correction.

In Figure 3, we began to see some jumps in the blue data points. These occur where the potentiostat is changing current range, and the built-in corrections for the cable are slightly different from the cable being used for the measurement. The red data points demonstrate the correction algorithm is beginning to show measurable effects.

Finally we tried a very small capacitor (47 pF). Data were acquired in Figure 4 with and without cable-capacitance correction.

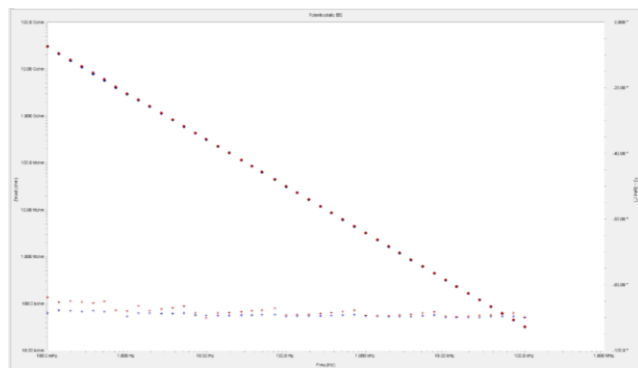


Figure 4. Superposition of uncorrected (red, Fig. 2) and corrected (blue, Fig. 3) EIS data.

Figure 4 shows the two sets of data overlaid, showing the improvement in the data after the implementation of the cable-capacitance correction. With no correction, the phase errors reach nearly 2° , and drop by a factor of four with correction. Notice how the abrupt jumps have all but disappeared.

How to correct for cable capacitance

If you think you can benefit from additional cable capacitance correction, perform the steps as follows.

1. Connect the cell cable to the Calibration Cell for your instrument, and place the Calibration Cell inside the Calibration Shield.
2. In Gamry Instruments' Framework™ software, click **Experiment>Named Script**, choose the `calcable.exp` script, and open it.
3. Select the **Cal Cable** radio button, confirm the correct Calibration Cell is connected, and click the **OK** button.

The system calibrates the cell cable.

More details are provided in our [Cable Calibration Quick-start Guide](#).

Remember, cable-capacitance correction is most useful on high-impedance, low-capacitance cells. Cable-capacitance correction is not useful for devices with lower impedances such as batteries, supercapacitors, and fuel cells.

A Word about our Calibration Shield

The Calibration Shield is a Faraday cage. There are times when experimenters have to take care with Faraday cages. Sometimes, when working with small signals, a noticeable stray capacitance develops between the electrochemical cell inside the cage, and the wall of the Faraday cage. Below you can see the discontinuities from stray capacitance on a very small EIS signal inside a Faraday cage:

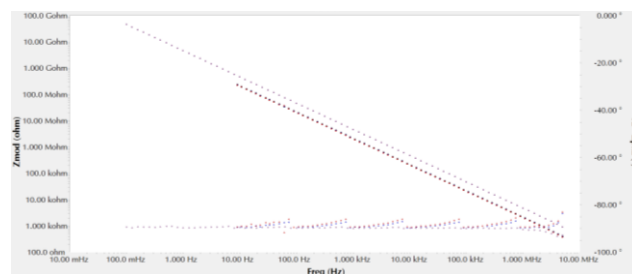


Figure 5. EIS with discontinuities caused by stray capacitance from the Faraday cage.

This phenomenon is sometimes observed with large, flat samples parallel to the Faraday cage's floor.

To minimize stray capacitance between an electrochemical cell and the Faraday cage, move the cell away from the walls toward the center of the shield.

Prop up the cell off the floor of the shield using a non-conductive object (e.g., block of wood, textbook).

Conclusions

Cable-capacitance correction in Gamry Instruments' software can be used to minimize small differences that show up in EIS spectra. As impedance decreases (capacitance increases), the effect of using this type of correction decreases. Uncoated metal samples and

energy devices such as batteries, supercapacitors, and fuel cells will see no useful effect of using cable-capacitance correction. For more information on Gamry Instruments' potentiostats and EIS measurements, see our website at www.gamry.com.

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