# Signal Processing of Vector Network Analyzer Measurement for Quartz Crystal Microbalance with Viscous Damping

QCM itself is a very sensitive mass sensor down to the order of a nanogram. We develop the measurement system which can extract both resonance frequency and resistance from QCM using a portable vector network analyzer (VNWA). Typically, to achieve certain sensitivities and specificities, special coatings are needed. However, many of coating materials are viscous. High viscosity worsens the Q-factor and signal to noise ratio.
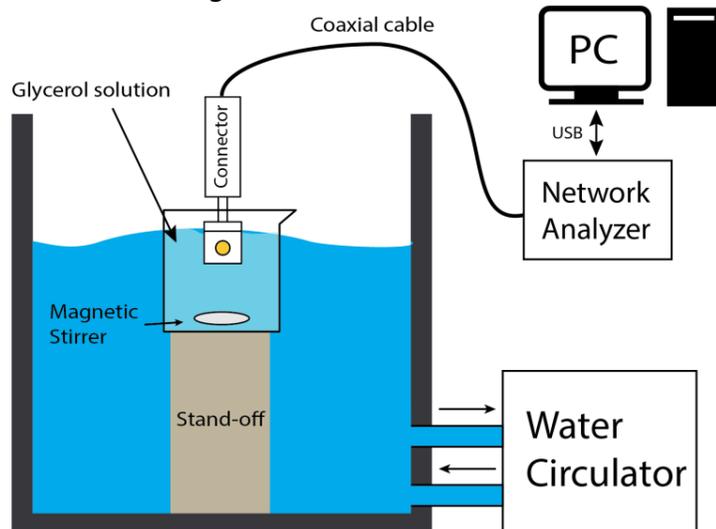

The experiment was carried out with aqueous glycerol solutions. Glycerol is known as a viscous liquid, water-soluble and non-toxic making a preparation simpler. The experiment setup is shown in the figure above.
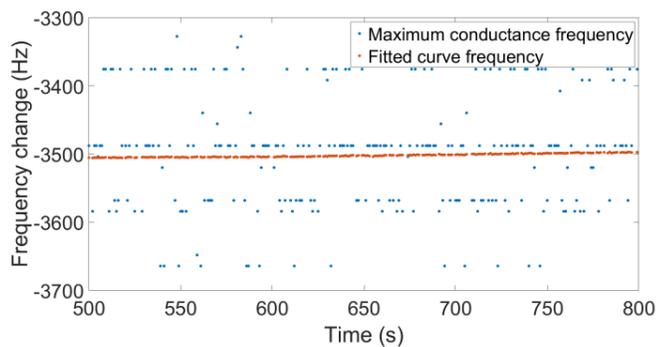
To counteract the noise problem due to high viscosity loading. The curve fitting method was used by utilizes all the datapoints within a certain frequency range. The QCM was immersed in a 40% glycerol solution as shown in the figure above. The frequency fluctuation is greatly reduced to a few Hz. When compared to the maximum frequency method, even under high viscous loading.
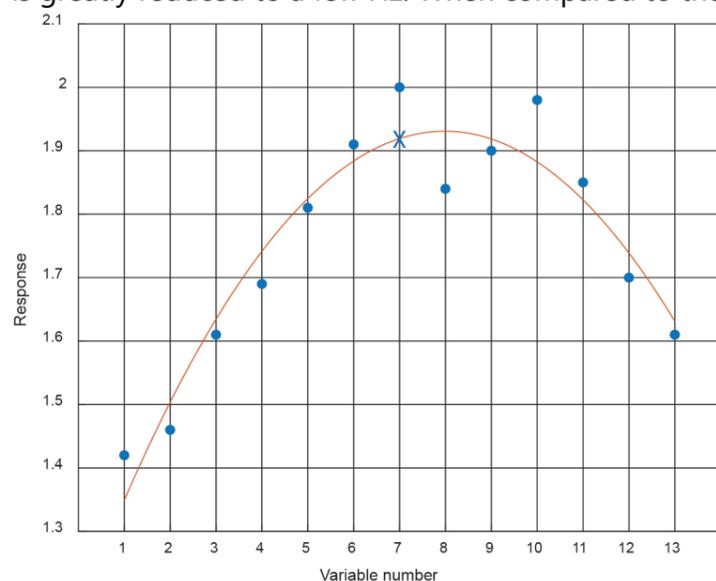
For further improvement. the data after curve fitting are applied to a Savitzky–Golay filter. The principle is 1) Determine the desired data point 2) Expand the window of data 3) Fitting data within the window using a polynomial 4) The center position of the window is the filter output. The above figure shows a polynomial fit with a window size of 13 points. The smoothed value of data point 7 is indicated as X.
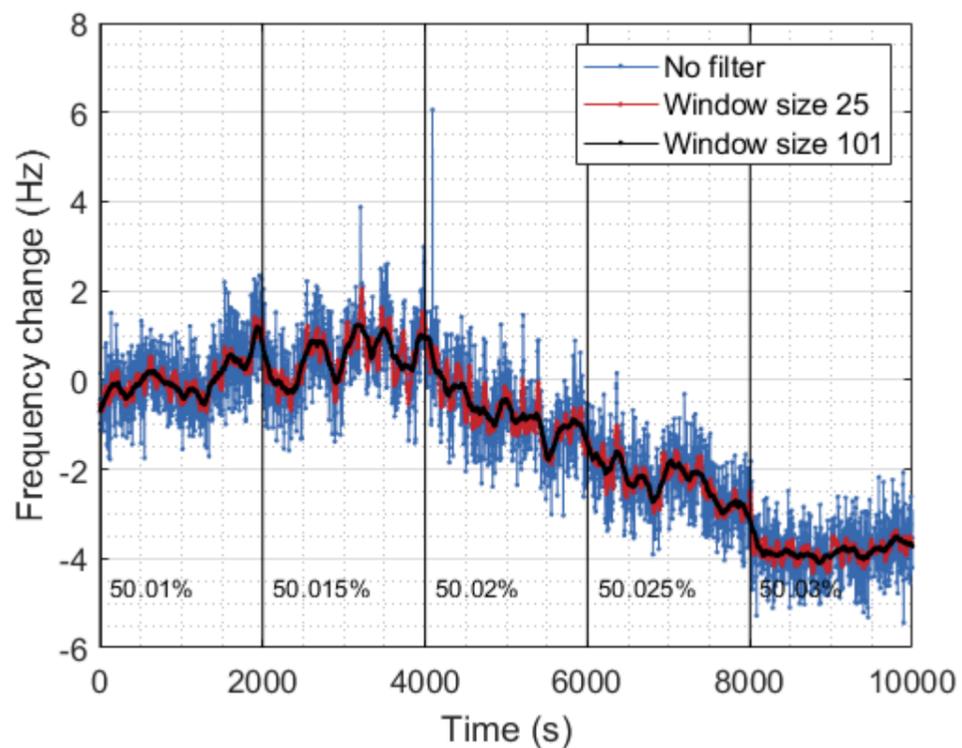
The experiments were conducted using a micropipette to add glycerol to the solution until concentrations of 50.01 %, 50.015%, 50.02%, 50.025% and 50.03% were reached. The frequency shifts without a filter and with a filter for polynomial order 2 and window size 51 and 101 is showed on the above figure. It was found that the fluctuation was reduced when the Savitzky–Golay filter was used. In conclusion, the SNR of a QCM with heavy viscous damping can be improved in real-time by applying the curve fitting technique to its frequency characteristic and by using a digital filter such as a Savitzky–Golay filter.