§48. Software for Real Time Display and Noise Reduction

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We successfully developed a UNIX-based data acquisition system on Sun SPARCstations for the superconducting magent experiment. Our task is to implement two new features—fast and easy display and efficient noise reduction.

Because superconductor wires are stabilized by good conductors such as copper and aluminium, the typical normal-state signal level between two taps on a conductor specimen is quite low (on the order of 1mV), thus necessitating noise reduction for data analysis.

We have developed two noise reduction methods for noise reduction. The first one is quite fast, and suitable for noise reduction on the fly. The second one, based on the least-squares method and moving averaging, is accurate but time consuming. We implemented both methods on UNIX workstations.

Note that almost all of the noise in our data is at 60Hz and its multiples, see the lower left part of Fig. 1.

The first methods is based on digital filtering in the time domain. It effectively cuts the direct-current and multiples-of-60Hz components. It is much faster than the oft-used filtering through fast Fourier transforms (FFT). As is the case with FFT, however, this method removes the multiples-of-60Hz components of both noise and signal, so it can result in the ringing phenomena.

The second method is partly interactive, in that it first allows the user to choose the time region in which there is no signal of interest. This can be done by two clicks on a mouse. Next, in this region we determine a_k, b_k, c_k, ω that minimizes the quantity

$$\sum_t \left[V(t) - \left(\sum_{k=1}^{m} (a_k \cos k\omega t + b_k \sin k\omega t) + c_0 + c_1 t \right) \right]^2 .$$

Then we use these these values of a_k, b_k, ω to calculate in each data point the expected noise

$$\sum_{k=1}^{m} (a_k \cos k\omega t + b_k \sin k\omega t)$$

which is to be subtracted from the data $V(t)$ in the whole region.

Experience shows that the number of harmonics m is 6 to 10.

To determine the rise point of a quench signal, it is not useful to fit sigmoid or step functions to the data, because the data usually exhibits complex behavior after the rise. Our experience shows that two good methods are (1) to use the point where the voltage rises above some predetermined threshold, and (2) to use the point of inflection. In case there is remaining noise, however, these methods do not tend to give unique rising points. One good method is to repeatedly apply moving averaging, with weights [0.25, 0.5, 0.25] for each of the three consecutive sample points. To find the inflection point, for example, we apply this averaging repeatedly until the numerical derivative values have a unique maximum.

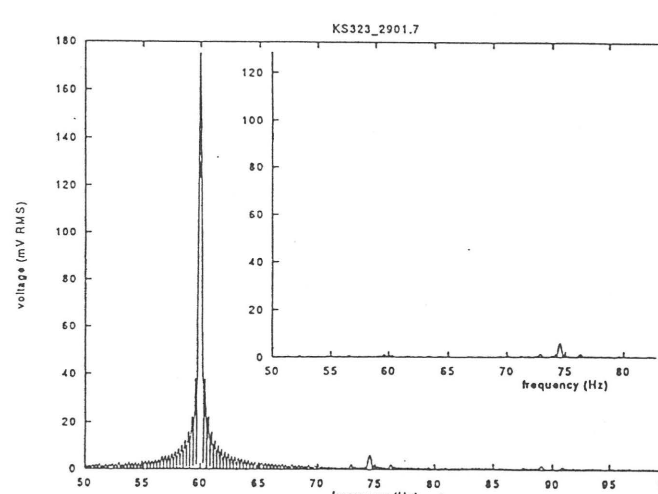

Fig.1. Typical spectrum of data before noise reduction (lower left), and after noise reduction (upper right).