

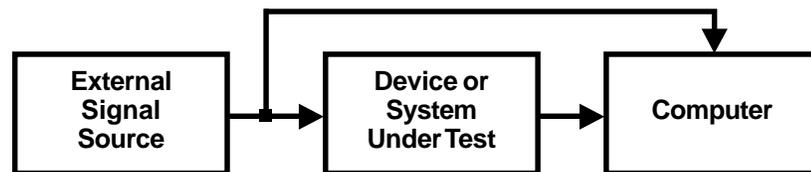


SIA Software Company, Inc.

## How Signal Alignment Affects the Quality of Transfer Function Measurement Data

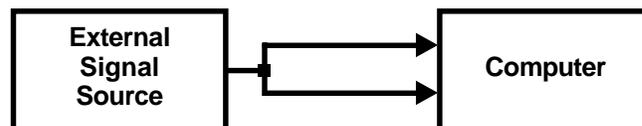
We are often asked just how critical it really is to set the proper delay for signal alignment in Transfer Function measurements. We will attempt to answer that question here. In this technical note, we will explore what happens when we send exactly the same signal to both computer sound inputs and then intentionally disalign the two input signals (in time) by adding delay on one input channel.

As you probably know, the SIA-Smart Pro Real-Time module's Transfer Function mode *compares* two input signals and generates a plot that represents how the two signals *differ*. Normally, a reference signal is split at the source, one branch is sent directly to computer input #1, and the other branch is sent through the device or system under test then back to computer input #0 as the *measurement signal* (as illustrated by the block diagram in Figure #1 below).



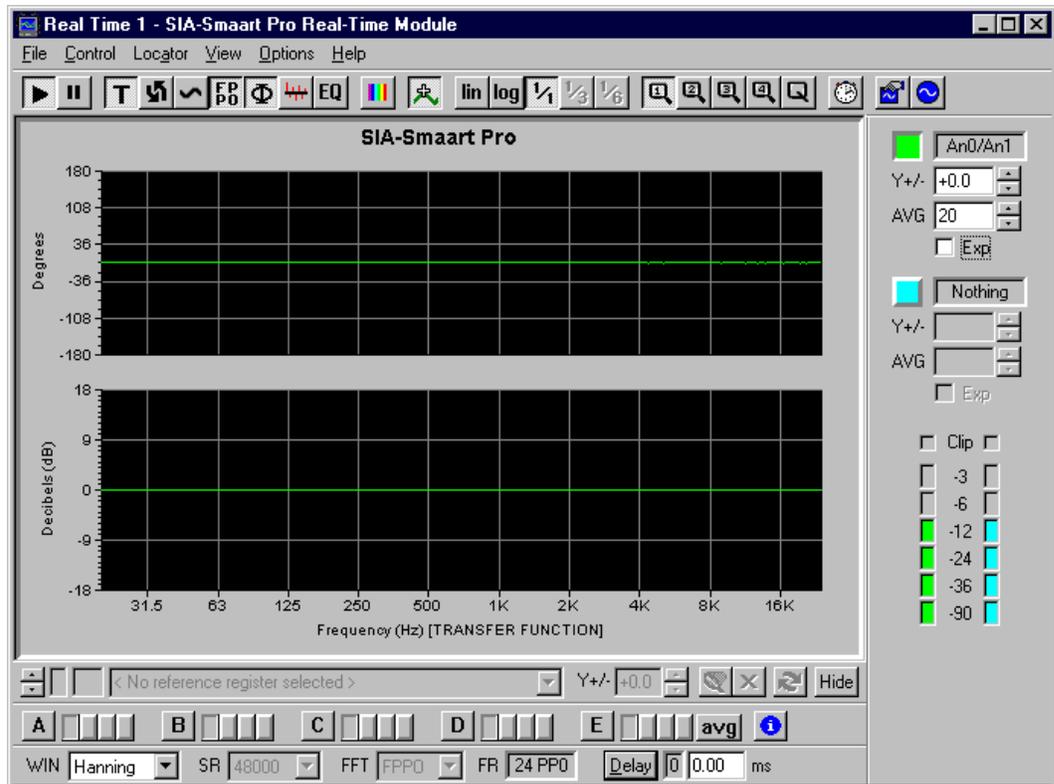
**Figure #1:** Block diagram of a typical Transfer Function measurement setup.

In this discussion however, we will be eliminating the middle box in Figure #1 above and sending the same signal to both computer inputs as shown in Figure #2 below. The only appreciable difference between the two input signals should then be the arrival time of the *measurement signal* when we start adding delay to input channel #0 to disalign the two signals in time.



**Figure #2:** Block diagram of the setup used for all example measurements shown in this document.

With both computer input channels receiving exactly the same signal — we used pink noise as a test signal to ensure we had sufficient energy all frequencies — at exactly the same time, we would expect to see a perfectly flat line on the Transfer Function plot with perfectly flat phase response at all frequencies and perfect (or near-perfect) coherence. And as Figure #3 on the next page shows, that's exactly what we get.

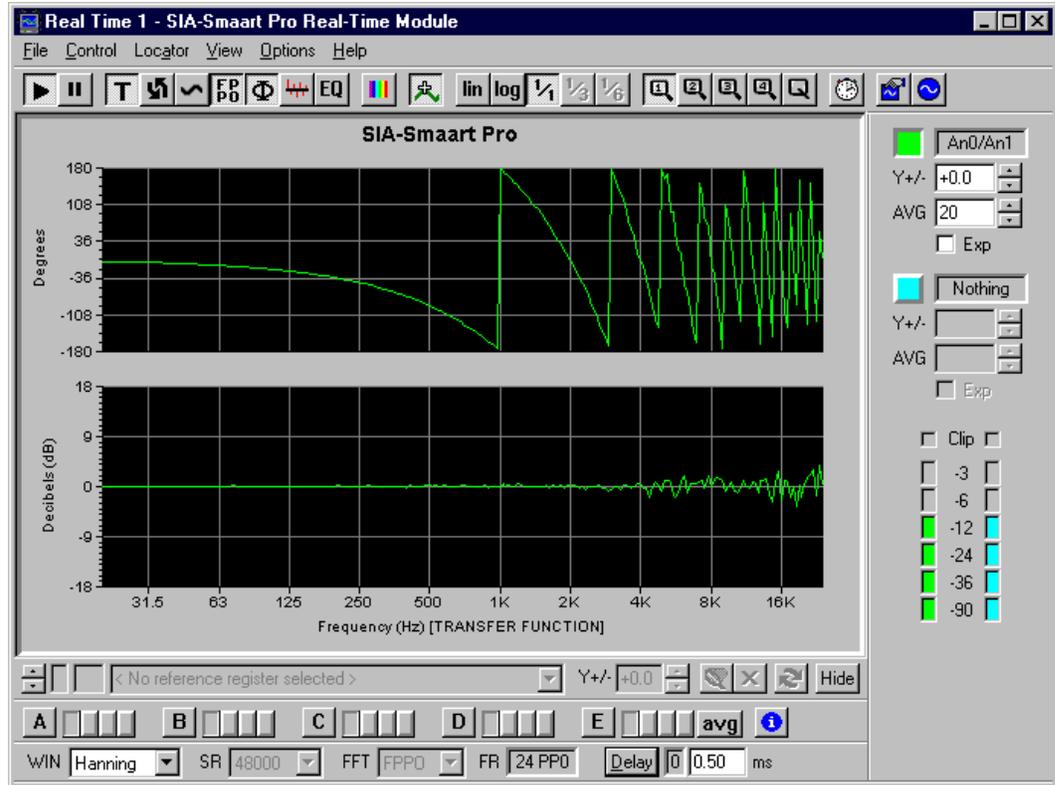


**Figure #3:** Magnitude and phase measurement of *one* signal sent to *both* computer input channels. Note that in this example, ***no delay has been applied to either input signal.***

The measurement shown in Figure #3 above was made using 24-point per octave FPPO resolution in Transfer Function mode. Pink noise was used as the test signal. Notice that the signal levels for both channels was -12db below full scale to allow for the crest factor of the source signal used. A look at the Real-Time module's *Coherence* function showed that all frequencies below 18.5 kHz had coherence values above 0.98 (i.e., virtually perfect coherence).

Figure #4 on the next page tells a different story. In Figure #4, the measurement setup and all input parameters were identical to those used in Figure #3 with one exception; a delay of 0.50 milliseconds was added to the *measurement* signal on analog input channel 0 (the green trace in 2-channel RTA mode) using the Real-Time module's internal signal delay. As a result, the reference signal (on channel #1) and the measurement signal (on channel #0) are out of alignment (in time) by 0.5 milliseconds.

The effect of adding this delay can be seen two ways. First, the *phase* plot shows significant phase shift at higher frequencies. Since the *wrapped* phase display was used in this example, you can see the phase plot "wrapping" above 1000 Hz where the amount of phase shift exceeded  $-180^\circ$ , forcing the trace to jump to the top of the plot (i.e., wrap) to continue the curve downward. If you were to unwrap the phase display (by pressing the [U] key) and zoom out ([Alt] + [+]) a few times, you would see that the phase shift in the measurement signal is in excess of  $-2500^\circ$  at 16 kHz!



**Figure #4:** Magnitude and phase measurement of *one signal* sent to *both* computer input channels. All measurement parameters are identical to those used in figure #3 except that **0.50 milliseconds of delay has been applied to the measurement signal on input channel #0.**

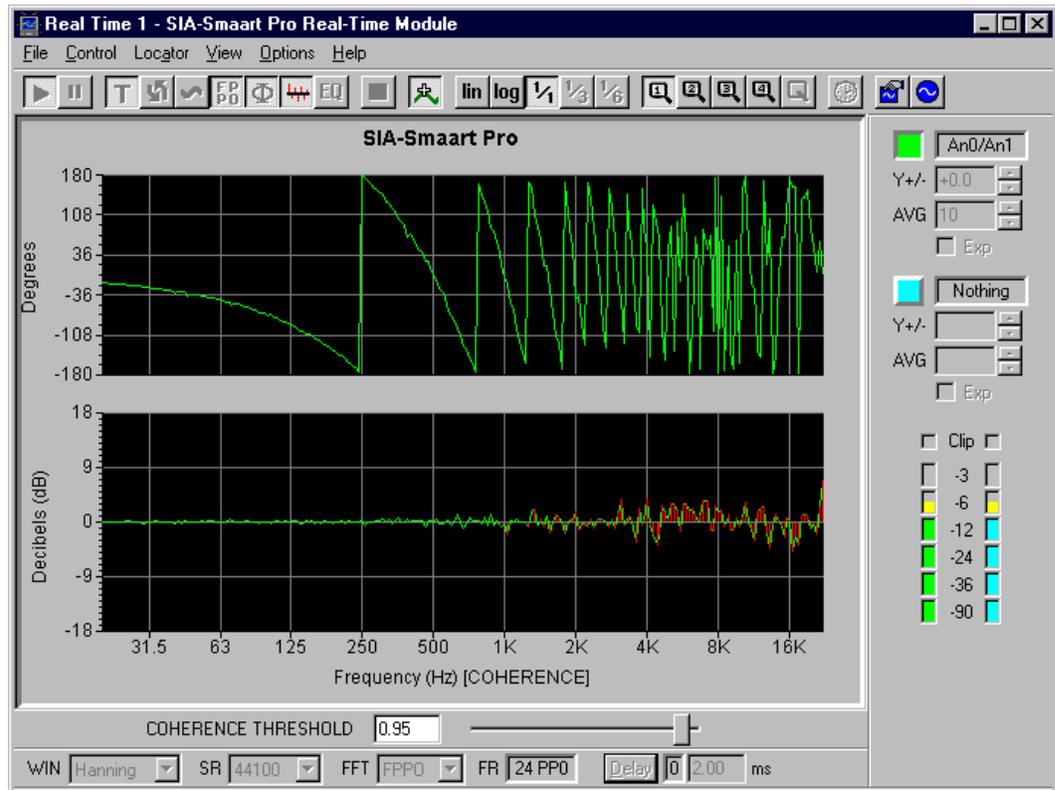
The fact that the first “wrap” in the phase trace shown in figure #4 occurs at exactly 1000 Hz is no accident. “1000 Hertz” is just another way of saying 1000 complete cycles per second. One full cycle can be expressed as 360 degrees. Therefore, at 1000 Hz, each full 360° cycle lasts 1/1000 of a second or 1.0 milliseconds. We delayed the measurement signal relative reference signal in this example by 0.5 milliseconds so at 1000 Hz, the relative time difference between the two signals is equal to one half of one full cycle or 180 degrees!

The misalignment between the two input signals can also be seen in the *magnitude* response plot (the “standard” Transfer Function plot in the lower half of the display). Notice that at higher frequencies the Transfer Function trace becomes more and more erratic compared to figure #3.

Another result of time misalignment of the input signals is a drop in coherence. The coherence function in Smaart Pro provides direct information about the quality of the data displayed in Transfer Function mode. The coherence function is typically used to answer the following three questions:

1. Was there enough energy at a given frequency to make a valid measurement?
2. Was there too much noise at a given frequency to make a valid measurement?
3. Are the two input signals properly aligned (in time)?

In Figure #5 (see below), the same signal is sent to both inputs of Smart and the FPPO transfer function is calculated. A delay of 2.0 milliseconds has been added to the reference input signal. The resulting graph shows an erratic frequency response at frequencies above 1kHz, and phase wrapping that begins at 250Hz. Again, this is as expected. At 250 Hz, one full 360° cycle takes four milliseconds so delaying one signal by 2 milliseconds should result in 180 degrees of relative phase shift.



**Figure #5:** The Transfer Function Coherence display. All frequencies that fall below the selected coherence level (as indicated on the slider below the magnitude display) are indicated by a vertical red line in the magnitude plot. As you can see, almost all frequencies above 1kHz indicate a drop in coherence due to the misalignment (in time) of the two input signals resulting from a 2 millisecond delay applied to input channel 0.

The measurement results displayed in Figures #4 and #5 should help to demonstrate the importance of insuring that the proper delay times are used when making transfer function measurements. Also, these examples show how the phase display and coherence function can be used to help you “see” possible time misalignment in transfer function measurements.

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