Subject: Measurement signal types
Posted by Constantine on Fri, 25 Jan 2008 16:44:55 GMT
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There are a LOT of signals used for acoustic in-air testing. Swept sine, pulsed sine, white noise, pink noise, TDS, MLS, impulse, chirp and dual tone. What are the differences between these and how are they used? What is the difference between TDS, MLS and impulse?

Subject: Re: Measurement signal types
Posted by Keith Larson on Sat, 26 Jan 2008 20:39:30 GMT
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Hello ConstantineThe first thing to do is split these signal types into some categories.Monotonic single frequency : Swept Sine (or sine) and pulsed sine---Monotonic signals exhibit the highest level of energy density, because the signal resides at only one frequency. This allows a measurement device to 'focus' on that one frequency using a narrow band filter rejecting only that one frequency. The other advantage is that the system is not being hit with many frequencies at once and therefore is responding to only the fundamental. In a mechanical system (a driver) there will be energy storage at this one frequency, but no others. Typically, the system will wait for the signal to settle, take its measurement and then (if required) move on. Monotonic signals will exhibit the highest signal to noise ratio, but in an acoustic measurement, reflected or standing waves can become significant. Broad-band signals, by the way, are NOT immune to reflected energy, but there is a trick that can be applied to deal with them. Another advantage of monotonic signals is that harmonic analysis is possible as there is only one excitation frequency.A pulsed sine is an interesting hybrid. By turning on and off the signal source and then gating the signal as it comes back, room reflections can be somewhat mitigated. This, however, is often not as simple as it may sound, since the pulse might not fully excite the system. In addition, there may be a frequency dependent time delay. The solution in this case is to make the time gate adaptive, or significantly widen the gate.Broad-band (all frequencies at once): Impulse, pulse, white & pink noise, MLS, chirp and TDS (Time Delay Spectrometry)--Broad-band signal types generate all frequencies simultaneously and are therefore useful in real-time measurements where the entire spectrum is displayed in one step. This is great, but these signal types also have relatively low energy density resulting in lower signal to noise ratios. Impulse, white noise, or white MLS signals all have the same amount of energy per signal bandwidth, but differ in magnitude and time(s) when energy is applied. A true impulse, for example, applies all of its energy in one single very big pulse. Not only is this difficult to generate, but the device under test must also be able to handle the impulse without distortion (it is unlikely you will ever see a true impulse in use). White noise and MLS are different in that they spread this energy over time. This lowers the peak signal level, but again there are differences. If you pulled out an oscilloscope you would find that a true 'white' MLS signal is a series of varying-width square waves going from +V to -V. In this case, the variable width is used to spread the energy as much as the start and end time positions of each square. The bottom line is that for MLS the device being tested needs to withstand a barrage of square waves. On the other side, white noise is a random walk process and is a little less abusive (and looks more like music).Mathematically, in theory, each of these cases will produce the same result. This assumes the system is linear and does not distort. However, in a real world non-linear system you will find that response depends on crest factor and energy density. Crest factor is the ratio of the largest to smallest average signal. The impulse would score highest, followed by MLS and then white noise. You will find that each signal type has different attributes that end up exciting the system in different ways and sometimes exposing particular traits like non-linearities. Mathematically, system response is based on the fact that the excitation signal contains all frequencies at once. The system response is derived as a ratio difference (in db) of the broad-band response of what went out to what came back. A 'pulse' is yet another interesting broad band signal. It can be a square wave or (as in our tools) a sawtooth. This signal type is well suited to low frequency measurements, but it can also mechanically bias the device under test. This can be a negligible effect, or it might excite an interesting phenomena worth measuring (all signal types are different).Pink, brown or other coloration's of signals are created when the signal is first passed through (typically) a low pass filter. All frequencies are still present but the low frequencies are now stronger relative to the highs. In this way you can, for example, have equal amounts of energy on a per octave rather than a per hertz basis. More importantly, depending on what you want to measure, this will concentrate more low frequency energy and improve signal to noise ratio at the bass end of the spectrum. Pink and brown noise is considered to be more like music, and is therefor often preferred in real-time analyzers.I view the chirp and TDS as hybrids. A chirp signal is nothing more than a sine wave that starts at low frequency and progresses upward over a period of time. TDS is a chirp signal receiver that can be built as a physical circuit, or implemented as an algorithm. Using quadrature signal paths and time delays, a matched filter is created such that the signal being generated is time matched to the signal coming back from the system. It is much easier, and common, to compare the response using an pair of FFT's. Like the MLS signal there is zero variation of maximum to minimum levels, so you may want to consider this when testing a tweeter for example.Cool things you can do with Real-Time Signals---One of the neatest tricks you can do with an RT signal is mathematically reconstruct the impulse and step responses. Being able to see the impulse can be quite handy in that secondary reflections can be readily identified. If you then place a time window around the incident impulse, rejecting the secondary, the resulting response is that of the primary signal as if the environment was anechoic. The downside is that the data making its way through the time gate window is narrowed affecting the bass response. This is readily evident when the time gate window is examined with the pulse response.Which signal type to use:-------------------------Sine - All frequencies, highest signal to noise ratio (but can't reject reflections)Step - BassNoise - High frequencyChirp - High frequency, better bass, but can stress a tweeterMLS - High frequency, but can stress a tweeter(Our testers employ these, and more, signal types for both impedance and response testing)In the end, selecting signal types is about uncovering stress conditions.Hope this helps,Keith Larson

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Subject: Re: Measurement signal types
Posted by Constantine on Mon, 28 Jan 2008 02:34:36 GMT
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WOW! Thanks Keith that post is printing right now. It's one to keep for reference. Thanks for taking the time to spell that out in such detail!

Let me see if I understand the high points.

1. Sine and swept sine are best for signal to noise but can't reject reflections. Good to use outdoors I imagine.
2. Pulsed sine gates the signal as it comes back so room reflections can be somewhat mitigated.
3. Noise is good for high frequency testing but not as good for low frequency testing.
4. MLS is theoretically the same as noise but has a slightly higher crest factor so it may expose nonlinearities more than noise. MLS uses a series of varying-width square waves going from +V to -V.
5. Chirp is better for bass, good for treble but may stress a tweeter.
6. TDS is basically the same as chirp. They use a sine wave that starts at low frequency and progresses upward over a period of time. TDS is a chirp signal receiver that can be built as a physical circuit, or implemented as an algorithm.

I have a couple more questions, if you would be so kind to explain.

I am unclear about the differences between swept sine, chirp and TDS. Is the difference that a swept sine measurement uses filters to track the signal and lock on but chirp and TDS measure the signal as a single burst? I am thinking the swept sine is really a series of individual set frequencies one after the other but chirp is a fast moving sweep that is treated as a burst. Is that it?

You said chirp and TDS use "quadrature signal paths and time delays, a matched filter is created such that the signal being generated is time matched to the signal coming back from the system." Are they looking for a difference between what they expect and what they get from the microphone? There is a reference signal and what comes back is compared? Is that how it works?

You said "It is much easier, and common, to compare the response using an pair of FFT's." How does this work? Can you explain the process for an interested amateur?

C

Subject: Re: Measurement signal types
Posted by Keith Larson on Mon, 28 Jan 2008 14:19:59 GMT
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In my original google search I found this document containing a good deal of what you are looking for. What you will eventually find is that given a non-linear world, not all signal types or processing methods will produce the same results.

Transfer-Function Measurement with Sweeps

Keith

Subject: Re: Measurement signal types
Posted by Constantine on Mon, 28 Jan 2008 14:52:27 GMT
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Much appreciated Keith. Another one for the printer.C

Subject: Re: Measurement signal types
Posted by Wayne Parham on Tue, 29 Jan 2008 14:28:16 GMT
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Good stuff, Keith, thanks. What's impressive to me is your system has all these signal types available for acoustic testing so you can choose whichever one is best for your situation.
Smith & Larson WTPro/ST

Subject: Re: Measurement signal types
Posted by Keith Larson on Mon, 11 Feb 2008 09:15:30 GMT
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Hello Constantine and Wayne

I have been meaning to get back over here to post a response for several days now but have been both busy and distracted.

Yes, having multiple signal types is a definite advantage when dealing with non-linear systems that respond differently to varying levels and signal types.

A tweeters for example might be sensitive to low frequency signals mechanically biasing the diaphram. The step/impulse signal is the most low frequency energetic while white noise is the least. It might therefor make sense to use a white noise signal to test a tweeter. Or, maybe not if you are looking into these effects. That is, suppose you have a 40Vrms 300Hz signal and a first order tweeter crossover at 3Khz. The tweeter would see that 300Hz signal at only -20dBV or 4Vrms. Do you suppose that tweeter might sound just a little strained?

Another example I like to point out is driver TS parameters, since these vary quite a bit with drive level. I have for example, seen the Fs of a totally broken in driver drop by more than 30% by simply changing the AC drive level. Since most manufacturers put out specifications at one drive level (and BTW, what is it?), we set out to produce a continuum of TS parameters with respect to drive level.

Continuing with drivers, consider that suspension and voice coil mechanical offsets induce a polarity dependency. You might for example consider white noise as safe. However, white noise *does* contain at least some low frequency energy and therefor will mechanically bias a driver.

Others, like the step function are far more obvious as you can easily see a cone moving inward or outward. On the other hand, a chirp is somewhere between these extremes. In this case the DC bias occurs over each half sine period since the +/- half wave that follows is not symmetric. The bottom line is that all non sine signals can produce weird results, and sometimes all you have to do is flip the test leads!

I guess the question comes down to this: Is having the extra signal types an advantage? For me, tickling a problem and making it worse is sometimes more informative than trying to make it go away. Understanding the nuances can however be as one friend puts it, "like trying to take a sip from a fire-hose"

Best regards,
Keith Larson