FFT Spectrum Analyzer

Zurich Instruments

Spectrum analyzer integrated in HF2LI / HF2IS / HF2PLL - ZoomFFT

Technical Note
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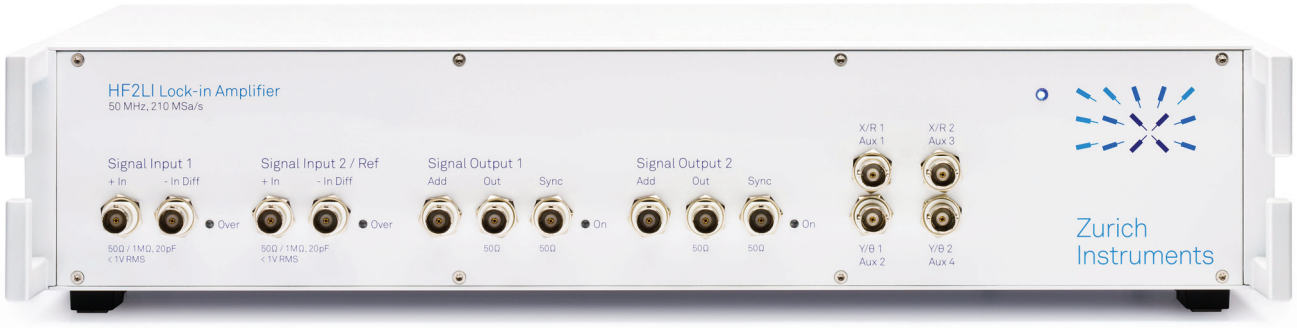

Introduction

FFT spectrum analysis is a very efficient method to calculate the power density spectrum of a frequency range of interest. This spectral analysis is computed on a pre-defined number of digitized samples of the time domain signal. As it can be computed on any window of the digitized samples, it changes with time. In brief, it provides insight on the spectral components of the signal of interest in a window called frequency span.

The trend of today's laboratory equipment is to combine several instruments in one box under the control of one user interface. The combination of a lock-in amplifier and an FFT spectrum analyzer provides advantages such as a reduction in measurement setup complexity and improved ease of use.

Description

The resolution of an FFT spectrum is determined by the total length of time spanned by the samples and, contrary to common belief, not by the sample rate [1]. Therefore at high sample rates, large number of samples need to be acquired and computed in order to achieve a given resolution. Thus the FFT spectrum analysis may require inconveniently large processing power.

In order to cope with large spans a few approaches are possible. One could for instance use a low-pass filter and decimate the data to at least double the rate of the filter bandwidth (sample rate reduction, undersampling). In this way it is possible to cover more time with fewer raw samples.

Another approach is to downmix a relatively narrow window of interest into the baseband and perform the FFT computation on the reduced sample rate. This second method is often referred to as ZoomFFT [1] or hybrid-superheterodyne FFT [2].

ZoomFFT is the approach that ideally fits with a lock-in amplifier because the instrument contains the demodulator that performs the downmixing. The output of a lock-in amplifier is sufficiently narrow-band for efficient FFT analysis using reasonable processing power. Furthermore the output easily covers longer periods of time, providing the wanted resolution. Finally, each acquired sample in the baseband is equivalent to one line in the frequency span and therefore it is not difficult to compute spectra with several thousand lines.

Comparison

Table 1 demonstrates that sub mHz resolution FFT spectra can be produced using the super-heterodyning FFT method, and that phase noise and dynamic range of an integrated instrument are comparable to best-in-class instrumentation while resolution is much better.

Users of Zurich Instruments profit from excellent measurement performance without needing additional equipment.

References

[1] ZoomFFT, Bores Consulting
[2] Spectrum Analyzer, Wikipedia (English)
[3] SR780 Datasheet, Stanford Research Systems
[4] ESA-L Series Spectrum Analyzers, Agilent, October 2009
[5] FMU36 Baseband Signal Analyzer Datasheet, Rhode & Schwarz, January 2007
[6] RSA3300B Series Real-Time Spectrum Analyzer, Tektronix, November 2007

Table 1. Comparison to commercial spectrum analyzers

Parameter compared	SRS SR780 [3]	Agilent E4411B [4]	R&S FMU36 [5]	Tektronix RSA3300B [6]	Zurich Instruments HF2LI
Product positioning	Low-end	Mid-end	High-end	High-end	Mid-end
Frequency range	DC - 102 kHz	9 kHz - 1.5 GHz	36 MHz	DC - 3 GHz	DC - 50 MHz
Frequency span (measurement analysis bandwidth)	195 mHz - 100 kHz	100 Hz - 1.5 GHz	0.5 Hz - 20 MHz	1 Hz - 15 MHz	220 mHz - 460 kHz
Maximum number of lines	100-800 lines	401	155 - 30'000	n/a	32'678
Best resolution	n/a	n/a	n/a	1 - 20'000 Hz	7 µHz - 14 Hz
Amplitude accuracy	±0.2 dB	±0.4 dB	±0.25 dB	±0.3 dB	±0.2 dB
Phase noise (all carrier frequencies)	n/a	-95 dBc/Hz @ 10 kHz	-135 dBc/Hz @ 1 kHz	-108 dBc/Hz	-125 dBc/Hz @ 1 kHz
Spurious free dynamic range (FFT-mode)	-90 dB typ	-77 dB	n/a	-70 dB typ	-90 dB typ @ 1 MHz
Sample memory	2 M - 8 M	8 M	16 M - 705 M	64 M - 256 M	Unlimited

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About Zurich Instruments
Zurich Instruments makes lock-in amplifiers, phase-locked loops, and impedance spectroscopes that have revolutionized instrumentation in the high-frequency (HF) and ultra-high-frequency (UHF) ranges by combining frequency-domain tools and time-domain tools within each product. This reduces the complexity of laboratory setups, removes sources of problems and provides new measurement approaches that support the progress of research.