Frequency Sweep Primer

Technical Note
Products: HF2IS / HF2LI / HF2PLL

Keywords: frequency response analyzis, linear sweep, logarithmic sweep, segmented sweep, harmonic sweep, calibration sweep

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Summary

The objective of frequency sweeping an electrical system is to identify points of interest in the frequency spectrum. Such points of interest are poles and resonances - these are important to know as they characterize the system. Frequency sweeping consists of applying a stimulus signal and then measuring the systems response to many frequencies, one after another. The results plotted show the power or the amplitude of the measured signal over the defined frequency range. The output can either be relative to the stimulus signal (in dB) or absolute (V_{RMS}/Hz). Frequency sweeping is also sometimes referred to as frequency response analysis.

A sweeper will be sure that no energy is left undetected during a sweep. In order to achieve this, the step size and the measurement bandwidth must be adapted accordingly.

The first part of this technical note covers several underlying principles of frequency sweeping. The second part focuses on the frequency sweeper integrated into the HF2IS / HF2LI / HF2PLL, HF2PLL, in particular it's functionality and usability.

Description

General Algorithm

Any frequency sweeper will follow a generic algorithm which is repeated for every measurement point within the defined range.

1. Set the oscillator to the measurement frequency.
2. If the sweeper is capable of auto bandwidth: calculate the filter settings so that the range between 2 measurement points is covered.
3. Wait for filters to settle: the time required will depend on the filter bandwidth and precision required.
4. Measure the response from the system at the specific frequency.
5. If the sweeper is capable of averaging, repeat a defined number of times and average the results.

A frequency sweeper requires a sinusoidal frequency generator and a demodulator to perform the amplitude and phase measurement.

Linear Frequency Sweeps

Linear frequency sweeps sample a frequency range at equally spaced measurement points. The bandwidth should be set to avoid gaps between the sampling steps. One method for instance is to set the bandwidth (3 dB point) to coincide with the previous frequency.

A large bandwidth is useful for covering a larger portion of the spectrum. However, it is also prone to pick up additional noise from the system.

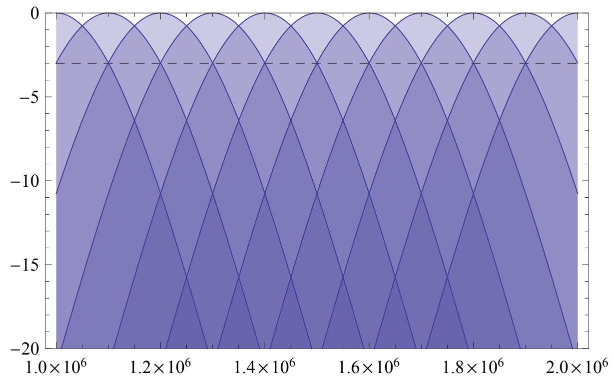

Figure 1. Linear frequency sweep from 1 MHz to 2 MHz: the dashed line indicates the minus 3 dB level

Logarithmic Frequency Sweeps

Logarithmic sweeps are useful for covering large frequency ranges in a short amount of time. The frequency measurement points are distributed logarithmically over the required range. Since the spacing of measurement points varies in this sweep strategy, unless the filter bandwidth is adjusted for each measurement point the resulting sweep, figure 2, shows gaps in the data.

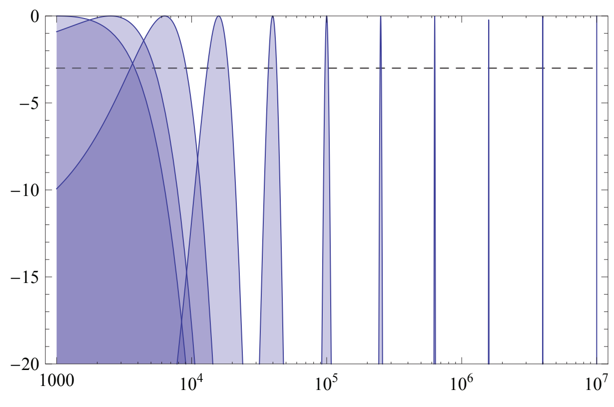

Figure 2. Logarithmic frequency sweep from 1000 Hz to 10 MHz with constant bandwidth of 1 kHz

A more suitable strategy for logarithmic sweeps is to set the 3 dB point of the following frequency to coincide with the previous frequency. The result of the method is depicted in Figure 3 with the peculiar unsymmetrical aspect of the bandwidth being due to the logarithmic scale of the frequency.

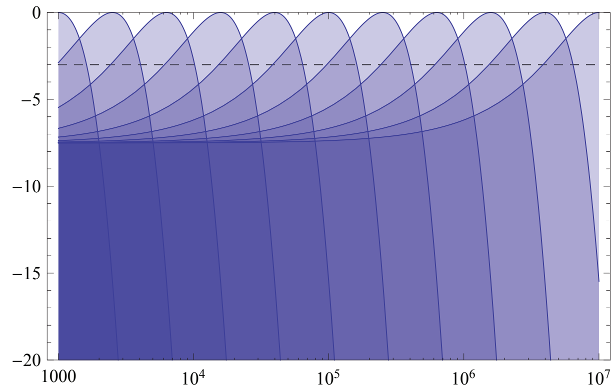

Figure 3. Logarithmic frequency sweep from 1000 Hz to 10 MHz with automatically adjusted bandwidth

Segmented Frequency Sweeps

This sweep strategy consists of a defined arrangement of individual frequency ranges (segments) that are subsequently swept. The increment within a segment could be linear or logarithmic. The benefit of this sweep mode is that we can focus on a number of interesting frequency ranges and omit those that are not of interest.

Harmonic Frequency Sweeps

There are situations which require a system to be swept with a fundamental frequency but with the measurement taking place at a higher harmonic of the fundamental. An example would be an oscillating beam that is driven with the first harmonic while the speed is to be measured on the second harmonic.

Sweep Time

The time that it takes to perform a sweep is influenced by several factors. Generally low resolution sweeps will be limited by the execution time of the software, while sweeps with high frequency resolution will be limited by the theoretical maximum speed. Consider the following formula for determining the theoretical time taken to perform a frequency sweep:

$$T_{sweep} = 5 \times N \times PR \times \frac{FO}{2 \times \pi \times BW} \times AV$$

- N = number of measurement points between the start frequency and the end frequency
- BW = measurement bandwidth at each point; related to the time constant TC = FO / 2 * π * BW
- PR = precision; number of stable digits in the result, roughly equivalent to the settling time in time constant TC (1 digit precision is equivalent to the integration over 1 TC period)
- FO = filter order; a factor that determines the steepness of the filters, thus also the bandwidth
- AV = number of averages performed per measurement point; higher averaging reduces the noise and increases the signal-to-noise ratio

Calibration Sweeps

The purpose of calibration is to depict the changes between a selected sweep and subsequent sweeps. This behavior is particularly useful where changes in time are of interest rather than the absolute values. In general the deltas are small and therefore the sweeper will practically magnify the changes in phase and amplitude.

Sweep History

The concept with sweep history is to depict one sweep after the other in the same diagram with, for instance, different colors. The representation helps to visualize changes over time similar to the calibration sweep, but it depicts absolute values. This function can be effectively combined with all sweep modes previously mentioned. Individual sweeps can be saved.

Parametric Sweeps

Advanced frequency response analyzers allow the user to sweep across parameters other than just frequency alone. In principle, a parametric sweeper should be able to modify any specific setting while keeping all others constant. Sweep parameters of interest include output amplitude, output bias amplitude, filter settings, phase and time.

Benefits of Performing Frequency Sweeping with the HF2IS / HF2LI / HF2PLL

The HF2IS / HF2LI / HF2PLL are delivered with an integrated frequency response sweeper. It is a powerful tool with many supported modes. Nevertheless it is also possible to quickly operate the sweeper with just a few mouse-clicks and achieve excellent results. Advanced users can also take advantage of the more powerful features.

- The user is able to perform basic sweeping or has the choice of modifying instrument settings for more advanced sweeps
- The user requires less equipment to perform his measurements as the sweeper is seamlessly integrated into the same user interface as the main instrument
- The sweeper is provided with numerous settings and operating modes (linear, logarithmic, harmonic)
- Frequency sweeps can be performed at arbitrary frequencies with resolution as low as 0.7 µHz
- Supports auto-bandwidth setting
- Fully integrated with a spectroscope and oscilloscope - at no added cost to the main instrument
- Proven in the field

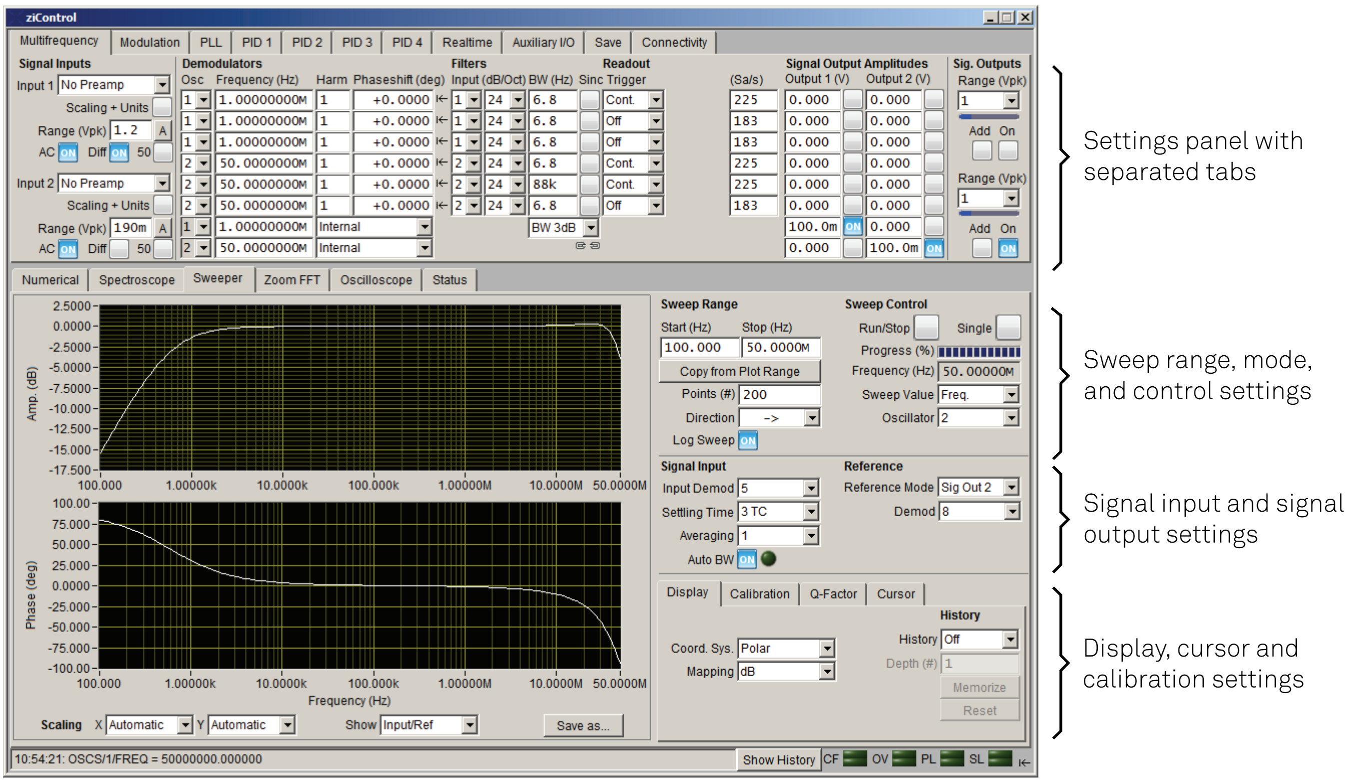

Figure 4. Screenshot of the frequency response sweeper of the HF2IS / HF2LI / HF2PLL for a logarithmic sweep from 100 Hz to 50

Scientists using the HF2IS / HF2LI / HF2PLL profit from the accuracy of a digital instrument which covers a frequency range that used to be only measurable with analog instruments, in combination with fully integrated functionality that will simplify laboratory life.

Glossary

Accuracy: inherent absolute precision of a measurement system compared to a calibrated or traceable standard.

Averaging: the average of a defined number of measurements, this will attain statistical precision for the overall measurement as signal-to-noise ratio is improved.

Bandwidth: the half of the range of the spectrum whose signal energy is considered by the demodulation and time integration.

Harmonic frequency: frequency being the double (2nd harmonic) or triple (3rd harmonic) and so on, of the fundamental measurement frequency.

Measurement point: frequency at which demodulation and time integration is carried out.

Precision: factor for the filter time constant for signal integration.

Settling time: the time required for a filter to reach a defined percentage of the final value after a change at the input of the filter; examples could be 10%, 50%, or 95% of the final value. The setting time is related to the time constant.

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