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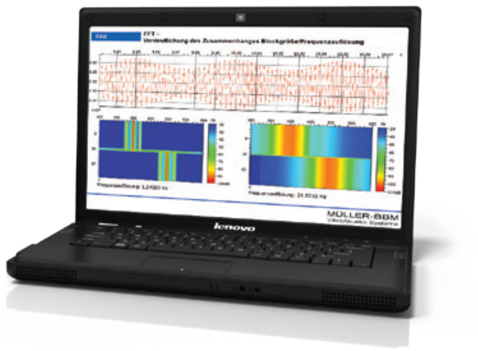
PAK



FREQUENCY ANALYSIS

The focus of interest in the broad field of NVH (Noise, Vibration, Harshness) is often on identifying the source of an annoying sound/ noise and/ or an unpleasant vibration. For this purpose, the signals first have to be digitized before they can be further analyzed with the help of a computer.

Frequency analysis is pivotal to the analysis of signals. It is a means to extract frequency information from the time signal. This white paper will give insight into this topic and elucidate the interplay of frequency analysis and PAK software parameters.

From the time signal to the spectrum

Figure 1a depicts a section of a time signal from a microphone channel. One can see clearly that the signal oscillates around its origin and is a superposition of several waves. A frequency analysis will be done to identify the dominant component frequencies in the signal.

There are various methods for doing a frequency analysis. The Fast **Fourier-Transformation** (FFT Analysis) is the most commonly used method in this regard. Other methods such as the **Nth Octave Analysis** or the **Wavelet analysis** are applied in other contexts with different objectives. This white paper describes the FFT Analysis in more detail.

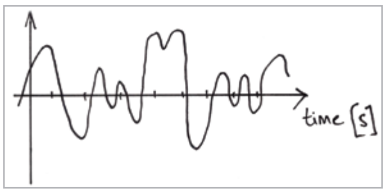


Figure 1a: Time Signal

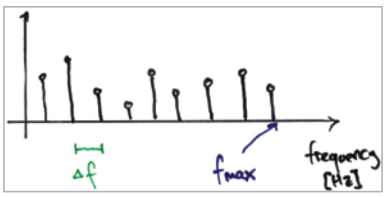


Figure 1b: Frequency spectrum

The outcome of the frequency analysis is shown in Figure 1b. The algorithm decomposes the time signal into sinusoids of different frequencies and plots these frequencies on a frequency axis.

The amplitude of each frequency component, i.e. a specific frequency line, is shown by its height and represents the energy at this frequency line (also called bin). The sampling rate of the signal determines the maximum frequency that can be analyzed. According to the **Nyquist-Shannon sampling theorem**, the sampling rate has to at least be two twice as high as the maximum frequency of interest. The PAK software features a safety cushion factor of 2.56. The maximum frequency that can be analyzed in this way is calculated by

$$f_{max} = {}^{f_s}/2.56$$

For example, signals sampled with a sampling rate of 48‘000 Hz, can be reliably analyzed up to a frequency of 18‘750 Hz.

Parameters of the FFT analysis

Every frequency spectrum has a well-defined number of bins, in which the distance of two bins constitutes the **frequency resolution**. The following relationship holds: the greater the number of frequency lines present in a signal, the smaller the distance between each of the lines and the more fine-grained the frequency information.

The frequency resolution is determined by the parameter **blocklength** which is a measure for how many samples of the time signal are used for computing the FFT (Figure 2). A bigger blocklength results in a finer or more fine-grained frequency resolution and utilizes a bigger section of the time signal to be subsumed to a frequency spectrum. Keep in mind that the short-lived events in an analysis block may not be distinctive in the spectrum.

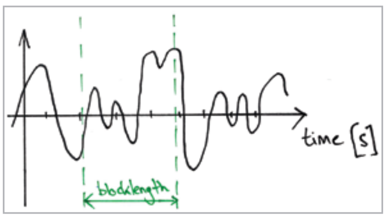


Figure 2: Blocklength of an FFT analysis

The PAK software allows one in addition to choose the type of windowing. By means of windowing, one can determine with what weighting the samples within a section (window) will be used in the subsequent computations. PAK features the following window types: Hanning, Flattop, and uniform windowing. To illustrate the effect of the windowing parameter, the FFT algorithm is described in more detail.

In an FFT, every analysis block has to be periodically continued. Discontinuities will be produced at the intersections of these blocks (Figure 3a), which cause an increase of all the frequency lines in the frequency spectrum. This is called the leakage effect. To prevent this effect, a weighting window can be applied to the analysis block, which reduces the values of the time signal to 0 at the start and the end of a block (Figure 3b), in this way preventing any discontinuities. This holds for the Hanning and Flattop windowing. The uniform window weights the signal uniformly with 1, so no dampening of the start or end of signal occurs. Therefore leakage effects will occur with this window type.

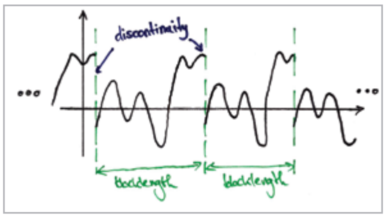


Figure 3a:
Discontinuities of an FFT analysis

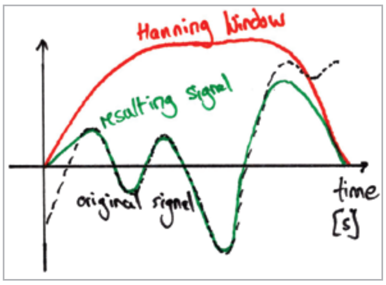


Figure 3b:
Hanning window

Frequency analysis of non-stationary signals

The FFT spectrum of a time signal is plotted in PAK via a **3D Campbell diagram**. One analysis block of the signal is used to compute a 2D spectrum for each analysis time point (increment). Ultimately all 2D spectra are then concatenated.

Using the Hanning windowing requires an additional parameter for the FFT analysis: the **overlap**. The Hanning window weights the signal component at the start and end of a block with 0 and has a passband of 1 for the center of the block. The transitional sections though, are strongly affected by the Hanning window and signal components are thus filtered, causing information loss.

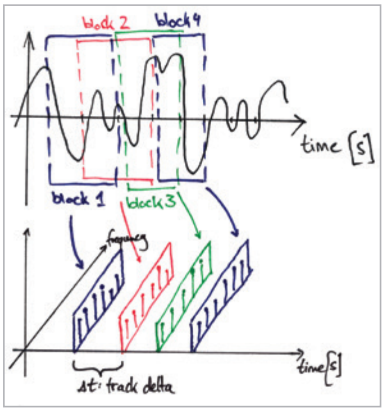


Figure 4:
Overlapping analysis blocks via the track delta

Therefore the PAK software allows for setting the overlap of analysis blocks to the track delta of the **track parameter** (Figure 4). For example, if a blocklength of 1 s is set, one can adjust the track delta to 0.5 s and the overlap to 50% of the analysis blocks. This will reduce the (filtering) effect of the Hanning window.

Summary

The frequency analysis represents the core method for extracting the signal information in the time domain. To apply this analysis technique successfully, the following aspects have to be taken into account:

- The sampling rate fs has to be at least 2.56 times the maximum frequency to be analyzed
- The bigger the blocklength, the finer/ more fine-grained the frequency resolution
- Hanning windowing reduces the leakage effect
- Overlapping the analysis blocks – controlled by the track delta – reduces the effects of Hanning windowing on the signal components at the start and the end of each block

The PAK software offers a multitude of tools for data acquisition and data analysis, especially for the fields of acoustic, vibration, structural and rotational analyses. PAK provides a flexible, effective and compact set of tools for all applications and is most effective in the context of highly standardized tasks and procedures, quality control or troubleshooting.

If you would like to gain a deeper insight into the field of signal analysis and other topics related to the analysis tools provided by Müller-BBM VibroAkustik Systeme, you are welcome to attend one of our practical training sessions. More information can be found at **http://www.muellerbbm-vas.com/services/training/.**

Müller-BBM VibroAkustik Systeme is one of the world's leading suppliers of vibroacoustic measurement technology. We focus on the interpretation of dynamic or physical data, especially in the fields of NVH, strength and comfort. For more than 30 years, our system competence results in innovative solutions that seamlessly integrate into existing environments.

Further Literature

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