SIGNAL ANALYSIS „DECRYPTED“

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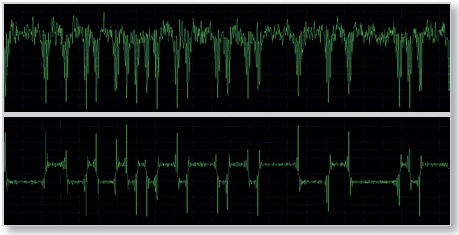
In the first part of this article (JED April, 2023), we discussed the importance of signals analysis for modern radio signals monitoring systems. The basics for analysis using the ‘Signal Analyzer’ software and the use of those results to adapt to new signals were described in detail. In this article, I would like to focus on the analysis methods used and how they work.

Various modulation methods are used in radio technology to transmit data (including digitized speech). The sender’s signal is modulated by one or more parameters according to the information to be transmitted. Generally, the basis is a sinusoidal signal which is modified in its amplitude (ASK), its frequency (FSK) or its phase (PSK). A combination of two parameters would be e.g. amplitude and phase (QAM).

In **time domain analysis**, plots of the amplitude, frequency and phase over time are displayed. Depending on the modulation type, symbols at ASK and FSK or peaks in the frequency with PSK become visible; also, a constant value e.g. at the amplitude gives hints.



Amplitude and frequency plot of FSK2 modulation

For this reason, time domain analysis can be used to recognize the modulation methods ASK and FSK and to determine parameters like shift (frequency spacing), the symbol duration or the order (number of signaling states used).

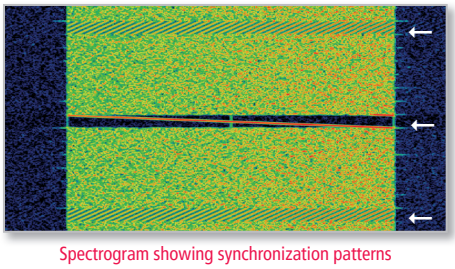
Another important method is **spectral analysis**, which includes e.g. the graph of energy over frequency, the spectrum. With it, the bandwidth of a signal can be measured or the type of modulation can at least be estimated on the basis of its appearance.

A special feature is the spectrum over the squared input signal. This measurement method is used to identify phase modulated signals (PSK). Starting from a sinusoidal signal, squaring doubles not only the frequency but also phase shift in the signal, as used in PSK for data transmission. With each squaring, the order can be halved until an unmodulated sinewave remains; a peak therefore appears in the middle of the signal’s spectrum. This is the indication of the PSK modulation; from the number results the order.

Spectra are also very good at detecting periodic changes in signals. This is ideal for measuring the symbol rate, since the data symbols are transmitted at fixed intervals. To detect only the changes in the signal, the derived signal is calculated. Since the direction of the change (values rising or falling) is irrelevant, the absolute value is formed and from this the spectrum is calculated. At the position of the symbol rate a peak can be found, its value can be easily read.

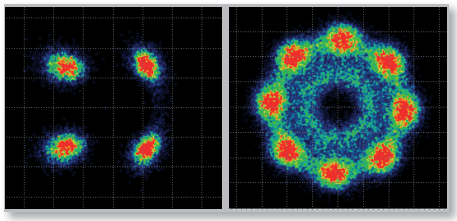
If there are fixed patterns or repetitions in the data, this can lead to further peaks with the repetition rate of the patterns, which can even represent the maximum according to their incidence. A simple example would be to transmit each symbol twice over a longer period of time, one would only be able to measure every second change and therefore measure half the value. Such cases are fortunately rather undesirable in the transmission technology, since the recovery of the information (demodulation) can lose quality. With channel coding, this behavior is generally excluded. The periodicity analysis described later aids the exclusion of such cases in the framework of the analysis.

Another important graph in the context of spectral analysis is the spectrogram. This 3D plot shows the behavior of the spectra over time, the signal’s energy levels are indicated by their color. The graph is well suited to visualize changes in the frequency spectrum over time, e.g. the start or end of a transmission, or to distinguish it from neighboring signals. For this reason, in the Signal Analyzer software the spectrogram is used at the very beginning of the analysis to select the signal to be analyzed.



Spectrogram showing synchronization patterns

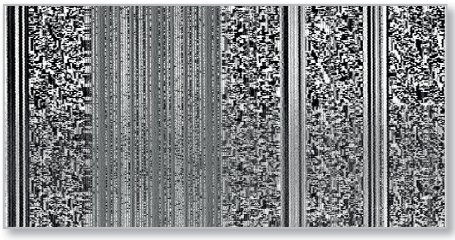
Phase- and Amplitude-modulated signals (PSK, QAM) can be analyzed easily with the **constellation diagram**, also called I/Q display. The graph uses a complex coordinate system and shows the In-phase (I) and Quadrature (Q) components of the modulated signal. Phase and amplitude states are shown as points or point clouds, if noise is present. The order can be counted from the number of points; the modulation/version from their geometry. As a variant there is the **differential I/Q display**. Here, not the absolute phase value is displayed, but the phase difference to the previous value. This allows differential phase modulation (DPSK) and variants such as π/4-QPSK to be identified by its constellation. Another advantage is that the constellation is visible even if the center frequency is not set exactly.



Differential and absolute I/Q display of π/4-QPSK modulation

For synchronization between sender and receiver, often repeating patterns are transmitted. The **periodicity analysis** uses a mathematical function to find such repetitions, the autocorrelation. The signal is compared with itself at different delays, and local maximum values at the time differences of the repetitions become visible.

In Signal Analyzer, an additional **Hellschreiber graph** is used to make these patterns visible. Here, different analysis values are displayed as brightness values line-by-line below each other. The duration of a line corresponds to the repetition time of the patterns; thus they always arrange themselves at the same position below each other, vertical lines become visible. Such frame widths are very typical for communication systems.



Hellschreiber graph showing repetitions

These and other analysis methods are part of the Signal Analyzer product from PROCITEC‘s go2signals product line. Bi-annual updates guarantee that the functionality is continuously expanded and adapted to the ever-evolving signal world. With release 23.2 (July, 2023), for example, new functions for Multitone (MFSK) modulation analysis and a signal parameter database have been added. In the near future we will add demodulation and bit analysis functions by adding an universal demodulator.
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