Digital signal analysis at bandwidths up to 500 MHz

The R&S®FSW signal and spectrum analyzer, equipped with the new R&S®FSW-B500 hardware option, offers analysis bandwidths up to 500 MHz. This innovation benefits users in research and development, for example. It can help them perform challenging measurement tasks associated with radar and satellite applications as well as on the components used for fast, wireless connections, including WLAN or Beyond 4G (5G).

**High bandwidths – challenging measurements**

The trend in digital wireless communications is toward ever higher data rates. This makes ever larger frequency bandwidths necessary for transmission. In wireless communications, the channel spacing for GSM was 200 kHz, whereas for UMTS it was already 5 MHz. The current LTE standard uses signals up to 20 MHz wide, which can also be bundled. The WLAN standards likewise require ever increasing signal bandwidths – IEEE 802.11ac currently requires up to 160 MHz. The DVB-S bandwidth for communications signals via satellite is around 30 MHz. Signals with a bandwidth of up to 500 MHz are planned in the Ka band for its successor, DVB-S2, under the name “DVB-S2 wideband”. Even wider signals are used in the microwave links that interconnect wireless communications base stations, for example. These signals are modulated in the E band at 71 GHz to 76 GHz with a bandwidth of up to 2 GHz.

The quality of these digitally modulated signals is characterized by parameters such as the error vector magnitude (EVM) and the total power dynamic range. These parameters can only be acquired by demodulating the signals. This requires signal analyzers with an analysis bandwidth that is at least as wide as the signal bandwidth.

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![Demodulation of a QPSK-modulated signal with a bandwidth of just under 500 MHz using an R&S®FSW.](image)
Analysis using signal and spectrum analyzers

Analysis of communications signals

Fig. 1 shows an example of the demodulation of a QPSK-modulated signal with an R&S®FSW signal and spectrum analyzer equipped with the R&S®FSW-K70 vector signal analysis option and the R&S®FSW-B500 option. In the table next to the constellation diagram, the analyzer displays the most significant parameters for characterizing the signal quality, including EVM as well as phase and symbol rate errors. The vector signal analysis option makes it possible to demodulate any modulated single carrier up to a bandwidth of 500 MHz and provides numerous other analysis functions, including channel compensation. In this example, the signal is analyzed at a sampling rate of 450 MHz. As a result of the RRC filter with a rolloff factor of 0.1, it has a bandwidth of just under 500 MHz.

The principle behind communications signal analysis using a signal and spectrum analyzer

In order to digitally demodulate signals, the amplitude and phase of the signal must be known. Spectrum analyzers are the instrument of choice for this task. Fig. 2 shows a simplified block diagram of a signal and spectrum analyzer. It receives the broadband signal and converts it to the first intermediate frequency (IF). The signal is then downconverted to a frequency of less than half the sampling rate of the analog-to-digital converter (ADC) and digitized. An FPGA or ASIC digitally processes the signals from the ADC for further analysis.

The first local oscillator sets the center frequency of the frequency range to be acquired. The bandwidth is determined by the sampling rate of the ADC, since according to the Nyquist-Shannon theorem the sampling rate must be at least twice the analysis bandwidth. Therefore an ADC with a sampling rate of more than 1 GHz is required for a 500 MHz analysis bandwidth. The entire signal path must be designed with filter bandwidths of more than 500 MHz.

During subsequent digital signal processing, the signal is first equalized in order to balance out frequency-dependent amplitude or phase changes in the signal path. Equalization takes place on the basis of calibration values that were acquired using a known, wideband reference signal. The analyzer then digitally downconverts the real sample values to the complex baseband. These I/Q samples are now filtered, and the sampling rate is adjusted depending on subsequent analysis tasks. All information within the acquisition cycle and the analysis bandwidth is contained in the I/Q samples. Finally, T&M applications can be used for further investigation and demodulation of the signal.
Short pulses require high bandwidth

Ever increasing analysis bandwidths are also needed for analyzing continuous or pulsed signals, such as those used for radar systems. In the case of radar equipment, the signal bandwidth that is used determines the range resolution. This important system parameter specifies what the minimum distance between two objects must be in order for them to be detected as individual objects. The higher the bandwidth of a radar transmission signal, the higher the range resolution.

Pulsed radar equipment often uses different pulse lengths. Pulse compression is frequently used for medium to long distances. Long modulated pulses are transmitted and compressed by matched filters in the receiver. For high range resolution when objects are very close to the radar device, extremely short pulses are required. Pulses of less than 8 ns are required to accurately resolve 1 m.

The time resolution that a signal analyzer needs for determining the pulse rise and fall times of radar equipment or for acquiring extremely short pulses is inversely proportional to the analysis bandwidth. The higher the analysis bandwidth, the more accurately time changes can be determined. Pulses with a pulse width starting at about 8 ns can be measured with an analysis bandwidth of 500 MHz.

Frequency-modulated radar signals

Portable monitoring radars and radar equipment used for driver assistance systems in motor vehicles often use frequency-modulated continuous wave radar. Signal sections in which the frequency changes uniformly are known as chirps. The distance from detected objects and their speed are calculated from the frequency difference between the transmitted and received signals. The range resolution is determined by the bandwidth of the chirps. A range resolution of 30 cm is achieved with a bandwidth of 500 MHz. Fig. 3 shows an example of a linear frequency-modulated continuous wave radar with an up-chirp (section with increasing frequency) and a down-chirp (section with decreasing frequency).

The usable bandwidth depends on which frequency bands the regulatory authorities have assigned to the specific applications. The 24 GHz band that is frequently used by automotive radar allows a bandwidth of 200 MHz. In the 77 GHz band, bandwidths of up to 2 GHz are used. A quality feature of this type of radar system is a constant chirp rate, i.e. the constant frequency change rate within a chirp. In order to measure the chirp rate, the analysis bandwidth of the signal analyzer must be at least the bandwidth of the signal.

Exceptional challenges for communications equipment components as well

RF components in mobile phones, base stations or WLAN equipment must exhibit linear behavior over a very wide frequency range in order to maintain good transmit and receive characteristics. Unwanted nonlinear effects, however, always occur in the upper power range of amplifiers. These degrade the signal quality and cause a higher EVM value along with interference in adjacent channels. The possible consequences are lower modulation depths and therefore slower data rates.

However, if these effects have been characterized, they can be digitally compensated. The signal is digitally predistorted upstream of the amplifier to counteract the distortion of the amplifier. Predistortion and distortion cancel each other out in the amplifier, and a linearly amplified signal is the result. To also detect and correct distortion products of the fifth order, the analysis bandwidth of the spectrum analyzers should ideally be five times as wide as the signal bandwidth.

Summary

The high-end R&S® FSW signal and spectrum analyzer can be used together with the R&S® FSW-B500 500 MHz analysis bandwidth option for all analyzer models up to 67 GHz across the entire spectrum. This opens up new R&D applications for measurements on digital communications equipment components. Even extremely wideband modulated signals up to 500 MHz such as those used in microwave links can be demodulated and comprehensively characterized. Amplifiers with a bandwidth of 160 MHz, which are required for WLAN IEEE 802.11ac, can be digitally predistorted. Radar developers who want to investigate short pulses or wideband chirps will likewise benefit from the high analysis bandwidth.

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