Simplicity now available: measurements on automotive radars in all bands

Fig. 1: The R&S®FSW85 signal and spectrum analyzer is the world's first instrument that can cover the frequency range from 2 Hz to 85 GHz in one sweep.

The high resolutions of automotive radar sensors require signal bandwidths up to the gigahertz range. For this reason, frequency bands around 24 GHz and 79 GHz are provided for these applications. Up until now, harmonic mixers had to be used for test and measurement because no analyzer was available that covered up to over 79 GHz in a single sweep. Rohde & Schwarz has now launched a signal and spectrum analyzer that outperforms all others: the R&S®FSW85.

Test and measurement for automotive radars: at the frontier of what is currently possible

Radar sensors measure the range, radial velocity and location of targets in the vicinity under any weather conditions. Thanks to good performance data and low costs, they lay the foundations for more and more assistance and safety functions in vehicles (Fig. 2), nowadays even reaching the compact class. Sensors for the automotive sector operate in the frequency bands around 24 GHz, 77 GHz and 79 GHz (see box on page 32 for details).

In order to detect and resolve two adjacent objects, the range resolution of the sensor must be higher than the separation of the objects from each other. However, wide signal bandwidths are required for a high range resolution. This is not just a challenge for signal generation and evaluation in the sensor, but also requires high-end T&M equipment for development, verification and standard-compliant analyses. The measuring instruments must cover the frequency range up to 81 GHz and offer analysis bandwidths up to 2 GHz. Signal and spectrum analyzers are the instruments mainly worth considering for this task, but up to now they only reached bandwidths up to 500 MHz and did not even come near the maximum input frequency of 81 GHz.

Now there is one that can: R&S®FSW85 signal and spectrum analyzer

Up until now, the frequency range of analyzers had to be expanded with the help of external harmonic mixers for measurements in the 79 GHz band. This setup, however, has no preselection, i. e. when the signal is downconverted to an intermediate frequency, the user sees both the signal and its image. This disadvantage can be avoided with an additional measurement for which the frequency of the local oscillator is shifted by double the intermediate frequency. This enables the analyzer to detect and then remove unwanted mixing products. However, this only works when the intermediate frequency is higher than half of the signal bandwidth so that the image and signal do not overlap. This is not the case for a majority of the available spectrum analyzers. Another factor to take into account is that it is cumbersome to reduce the input level in a suitable manner when measuring with harmonic mixers, for attenuators must be attached to the waveguides and then readjusted for each changing level.

With its frequency range from 2 Hz to 85 GHz in one sweep, the R&S®FSW85 (Fig. 1) is the first choice for radar applications in the 79 GHz band. Thanks to its integrated preselection, it displays the signal without unwanted mixing products when measuring the spectrum even if this is significantly wider than double the intermediate frequency. In addition, signals with different levels can be easily analyzed without having to adjust the input level using cumbersome external attenuators. The attenuator in the R&S®FSW85 takes over this task.

Radar-supported vehicle functions (selection)

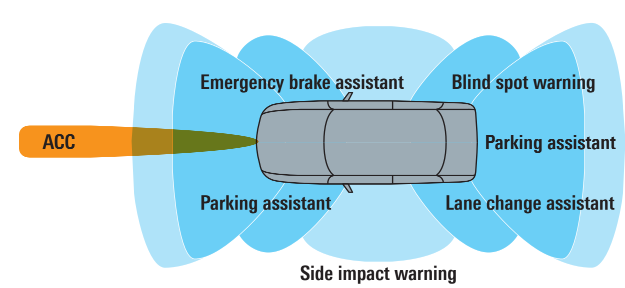

Fig. 2: Today radar sensors are used for numerous assistance and safety functions. Almost all of them require a high spatial resolution that can only be achieved with high bandwidths like the bands around 79 GHz.

Its internal analysis bandwidth of up to 500 MHz suffices for many automotive radar measurements. In the 79 GHz band, however, signals have a considerably larger bandwidth. For these applications, the R&S®FSW85 can be equipped with the R&S®FSW-B2000 bandwidth option. In combination with the R&S®RTO1044 oscilloscope, it can perform measurements up to a signal bandwidth of 2 GHz. The R&S®FSW85 downconverts the signal to an intermediate frequency of 2 GHz. The signal is then digitized by the oscilloscope, which acts as an A/D converter. This data is transmitted to the analyzer via LAN, where it is equalized and mixed into a digital baseband. The measurement applications in the R&S®FSW85 receive equalized I/Q samples as a basis for the analysis. The R&S®FSW85 fully controls the oscilloscope and transfers, processes, equalizes and analyzes the digital data. The signal path from the analyzer's RF input to the oscilloscope's A/D converter is characterized with respect to amplitude and phase response. The connection of the R&S®RTO1044 oscilloscope to the R&S®FSW85 is completely transparent for the user and measurement option operation is identical in all cases regardless of whether or not the A/D converter in the oscilloscope or the one in the analyzer is used.

For wideband, linearly frequency-modulated continuous wave signals like those used in automotive radars, the customized R&S®FSW-K60C measurement application is available. It records a signal up to 2 GHz bandwidth and analyzes it automatically. Important parameters such as chirp rate or deviations from ideal linear behavior are measured and displayed graphically or in tabular form. Fig. 5 shows a typical example.

Frequency bands for automotive radars

The frequency bands (Fig. 3), the emitted power level and the test requirements for automotive radars are defined in various standards such as EN 301091 V1.4.0. In Europe, automotive radars are temporarily using the 24 GHz band; however this must be discontinued by 2022. The European Commission has proposed the internationally available 79 GHz band as a replacement in its "79 GHz Project" [1]. The use of this band is currently being discussed and has already been accepted in many countries due to the significant advantages that it offers. Along with minimal limitations regarding the emitted power level and a smaller form factor for the sensors, it offers a wide signal bandwidth up to 4 GHz and a higher range resolution, as the following example shows: While a modulated signal bandwidth of 150 MHz allows a range resolution of one meter to be achieved, ten centimeters can be achieved at 1.5 GHz. The wider bandwidth also allows the integration of technical measures into the sensors to minimize interference between several radars, for example, frequency hopping.

Higher frequencies are not only helpful for the development of smaller sensors, they also help to improve the radial velocity resolution. The radial velocity resolution depends on the wavelength and the coherent processing interval of the radar waveform. If the coherent processing interval is kept equal, the radial velocity resolution improves by about a factor of 3 when the signal is emitted at 79 GHz instead of 24 GHz.

Chirp sequences are often used in automotive radars (Fig. 4), i. e. several linearly frequency-modulated signals with a duration of approx. 100 µs and a bandwidth of several hundred megahertz up to several gigahertz [2].

Fig. 3: Frequency bands for automotive radar in Europe.

Frequency band	Bandwidth
24 GHz to 24.25 GHz	250 MHz
21 GHz to 26 GHz	5 GHz
76 GHz to 77 GHz	1 GHz
77 GHz to 81 GHz	4 GHz

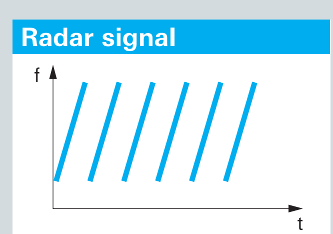

Fig. 4: Typical profile of a radar signal (FMCW radar).

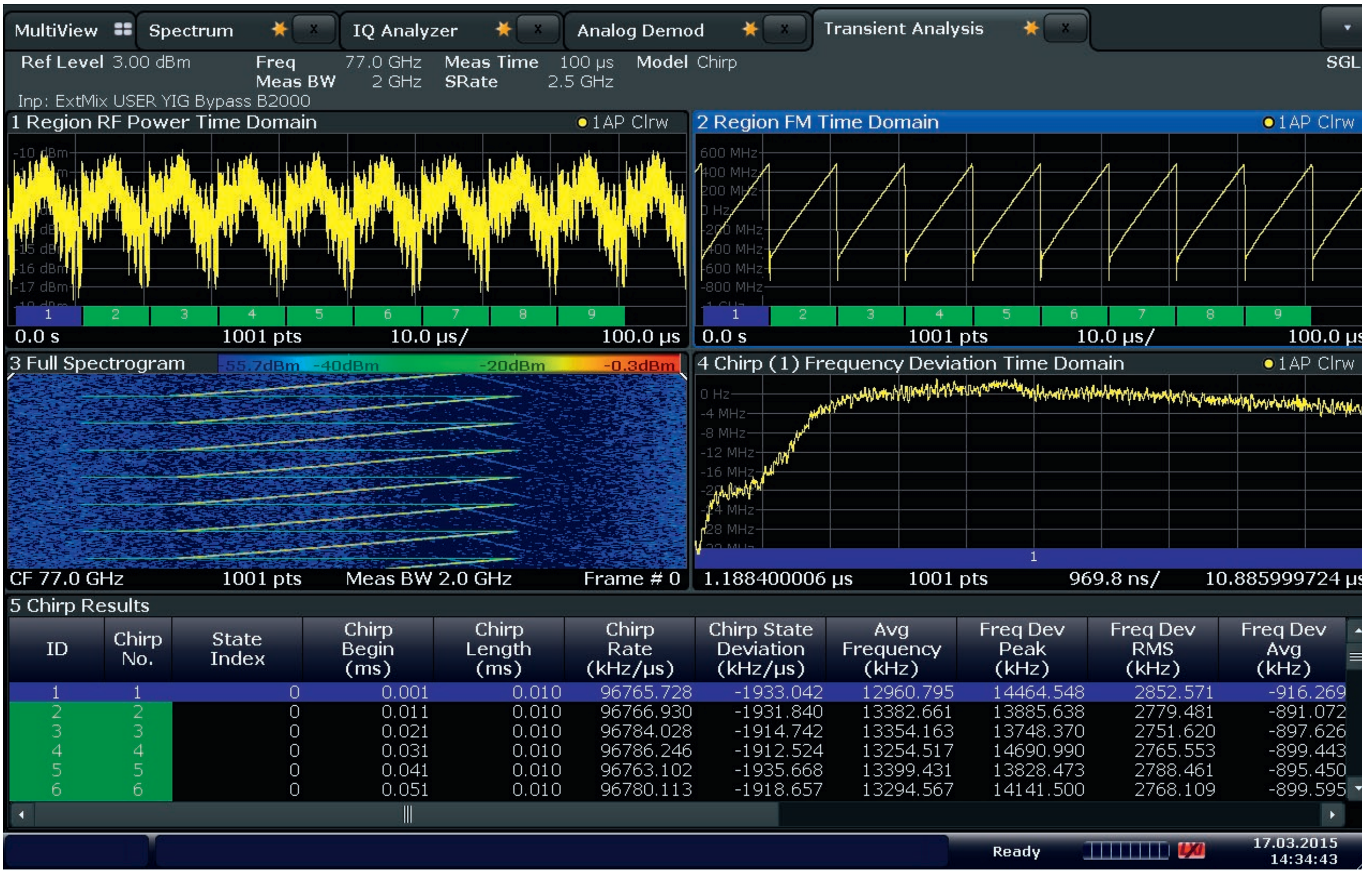

Fig. 5: Measurement of a 1 GHz FM chirp signal using the R&S®FSW-K60C option. Graphical depictions showing the frequency versus time or the power in the time domain. A table lists the most important measurement parameters.

Summary

Due to the considerable technical hurdles, until now there has never been a genuinely effective signal analyzer for measurements in the upper frequency bands (e.g. W band) for automotive radars. The R&S®FSW85 is not only the first instrument that provides sufficiently wide coverage of the input frequency range, it also provides analysis bandwidths that are indispensable for radar with high range resolutions. In addition, all important parameters can also be measured and displayed at the push of a button using the software option customized for automotive radars. The R&S®FSW85 is also well-suited for other applications in the frequency range above 50 GHz, such as the analysis of WLAN 802.11ad or 5G signals (see information under NEWS compact on page 6).

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Condensed data of the R&S®FSW85

Frequency range	2 Hz to 85 GHz
Phase noise	–137 dBc (1 Hz), 10 kHz offset at 1 GHz
Signal analysis bandwidth	up to 2 GHz
Total measurement uncertainty	< 0.4 dB to 8 GHz
Real-time analysis	up to 160 MHz bandwidth
Inherent noise 75 GHz < f ≤ 85 GHz	typ. –128 dBm/Hz

References
[1] See “79 GHz Project” at www.79ghz.eu.
[2] Rohde&Schwarz White Paper; Heuel, Steffen; “Radar Waveforms for A&D and Automotive Radar” (search term: 1MA239).