ANALYZING AUTOMOTIVE RADAR SIGNALS WITH AN OSCILLOSCOPE

Automotive radars on the test bench

eBook | Version 01.00

ROHDE&SCHWARZ

Make ideas real

SEEING THE WORLD THROUGH SENSORS

Driverless cars are virtually unique in symbolizing the power of future technologies and digitalization to alter our everyday lives. Connected, automated driving holds the promise of significantly higher road safety and convenience. However, trusting an autonomous vehicle is a big step for many people.

Five levels are defined for autonomous driving: assisted, partly automated, highly automated, fully automated, autonomous. Partly automated systems (level 2) already exist, and highly automated systems (level 3) ready for series production are being developed.

Together with other sensors such as lidar, cameras and ultrasound, radars play a key role in current and future advanced driver assistance systems (ADAS). Automotive radars act as eyes for the vehicles. They are already being manufactured in the millions, and in top-end vehicles they are standard equipment. Radars are not bothered by fog or snow. By measuring attitude, separation and velocity, they can foresee critical situations and avoid accidents.

The number of radar sensors per vehicle rises with each level of automation. Highly automated driving naturally places high demands on the technology. The latest systems operate in the microwave region to determine the range, velocity and relative angle of detected objects and perceive even minute movements. The only thing better than bandwidth is more bandwidth: the next generation of automotive radar sensors will use 4 GHz signal bandwidth.

Every radar component and its integration into the vehicle must be rigorously tested to ensure reliable operation. This eGuide describes how to measure and calibrate radar sensors using an R&S®RTP oscilloscope.

"Autonomous driving will come, but not as fast as some people think. A reliable legal framework is still missing. For example, some functions are allowed in the USA but not yet in Europe, And there are still many technical obstacles to be overcome."

Jürgen Meyer, Vice President Market Segment Automotive, Rohde & Schwarz


ROHDE&SCHWARZ RTP · Oscilloscope
Spectrum RX1
Spectrum RX2
Delta Mag. RX1 vs RX2
Delta Phase RX1 vs RX2
ROHDE&SCHWARZ SMA100B · Signal Generator · 8 kHz – 20 GHz
Frequency
12.666 666 600 000 GHz
Level
17.00 dBm

AUTOMOTIVE RADARS ON THE TEST BENCH

Compact radar sensors with long range and high resolution are currently being developed for driver assistance systems and future fully autonomous vehicles. Operating in the frequency range from 77 GHz to 81 GHz, the sensors use phased array antennas to obtain location information. The accuracy of the obtained data is directly correlated to the accuracy of the relative phase angles of the emitted signals, making precise adjustment of the antenna system a crucial factor for precision.

Due to the high frequencies, sophisticated T&M equipment is required to characterize these sensors in the development phase. For many of these measurements, the R&S®FSW85 spectrum analyzer with its large measurement dynamic range and sophisticated analysis features is an excellent choice. But it has only one input channel and is therefore unable to measure the phase differences of multiple signals. Oscilloscopes have an advantage here. The four-channel R&S®RTP, for example, can act as a phase coherent receiver and simultaneously analyze and compare up to four signals.

The R&S®RTP oscilloscope is ideal for characterizing the new generation of radar sensors. The radar signals are either acquired directly from the radar sensor as baseband signals or downconverted by a mixer to the oscilloscope’s bandwidth."

Dr. Ernst Flemming, Director of Oscilloscope Product Management, Rohde & Schwarz

TEST SETUP

External mixers are used to downconvert the radar signals to the oscilloscope's frequency range (Fig. 1). The R&S®FS-Z90 harmonic mixers in this example use the sixth harmonic of a local oscillator (LO) to generate the desired output frequency. An R&S®SMA100B HF and microwave signal generator serves as the LO, while the evaluation board of a commercial radar sensor acts as the radar signal source.

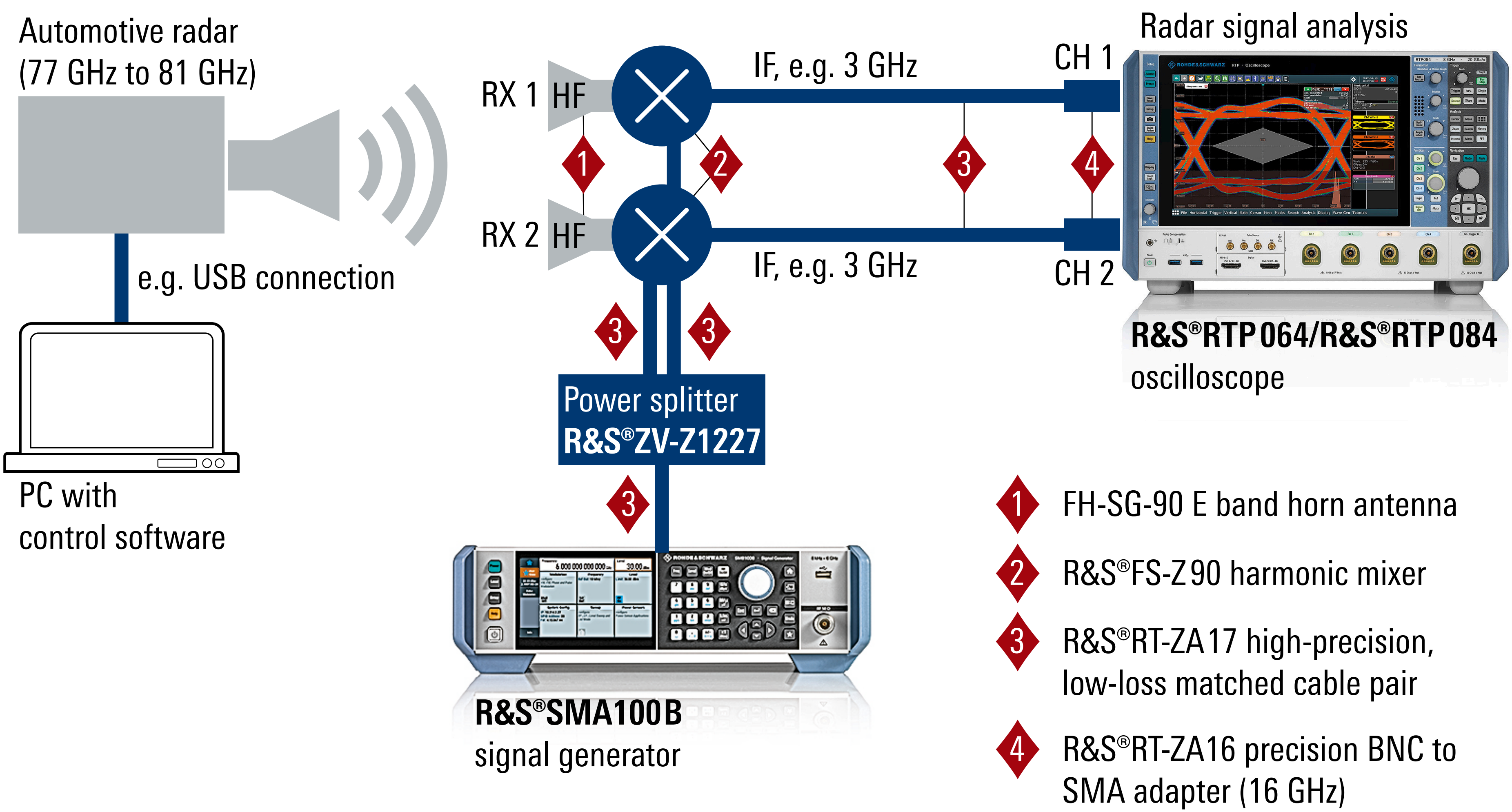


Fig. 1: Test setup for multichannel radar analysis with an oscilloscope. The radar signal is downconverted to an IF frequency of 3 GHz by the harmonic mixers and fed to the oscilloscope.
The power splitter and one mixer are not needed for a test setup with only one channel.

MEASUREMENT TASK

CONFIGURATION OF THE RADAR SENSOR

The radar system uses a chirp sequence signal consisting of several high frequency pulses in direct succession. Each of these pulses is a chirp with a bandwidth of approximately 4 GHz. The sensor is configured so that the frequency of the radar signal rises linearly from 77 GHz to nearly 81 GHz (up chirp). The end of the sequence is followed by a break of several milliseconds (interframe time). During this time, the radar processor calculates the locations and speeds of the detected objects.

DEEMBEDDING FUNCTION SIMPLIFIES SIGNAL ANALYSIS

The IF signals from the mixers are fed to the oscilloscope inputs. The attenuation and S-parameters of the individual components in the signal path can be taken into account by the hardware and software deembedding functions of the R&S®RTP. The impact of deembedding is illustrated in Fig. 2. The mixer attenuates the received signal over the entire frequency range. The received signal is detected with decreasing amplitude as the frequency increases (Fig. 2, left). Deembedding compensates for these losses (Fig. 2, right), enabling the oscilloscope to analyze the actual signal.

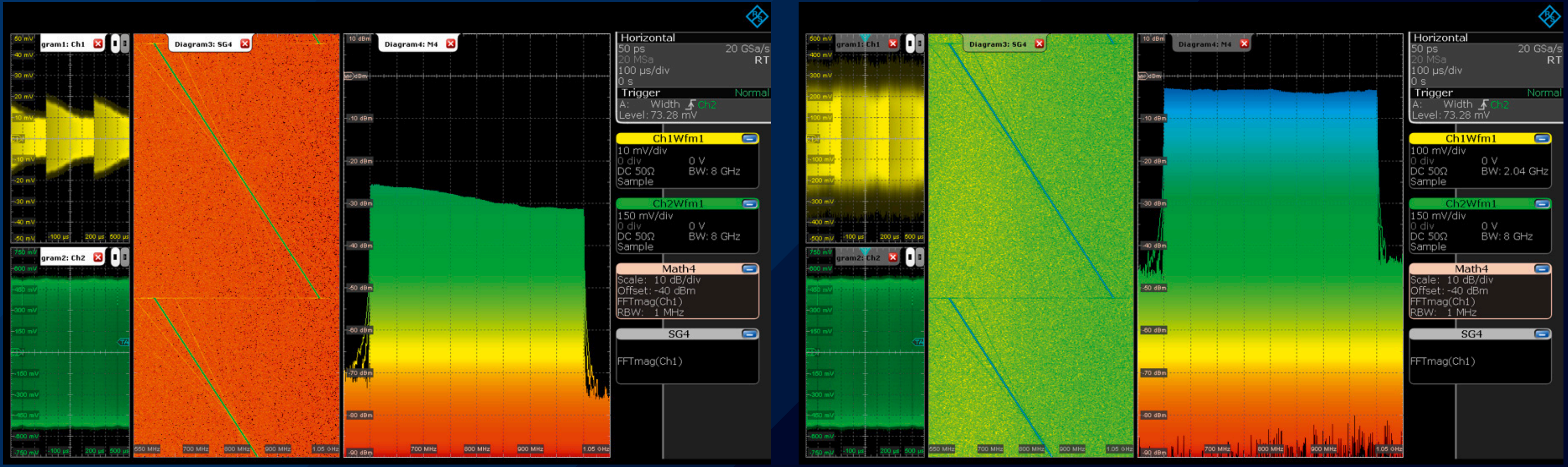


Fig. 2: An FMCW signal with deembedding disabled (left screenshot) and enabled (right screenshot). The frequency response correction reconstructs the signal in its original frequency range.

MEASUREMENT OPTIONS

SINGLE-CHANNEL ANALYSIS

Isolation of individual radar pulses with the width trigger

Stable trigger conditions are essential for reliable signal analysis with an oscilloscope. Oscilloscopes usually offer advanced trigger options in addition to traditional edge triggering. However, these options can only be used up to a certain bandwidth, depending on the manufacturer. Thanks to its digital triggering, the R&S®RTP can use the entire range of trigger options up to the maximum bandwidth.

Simple edge triggering is not useful for these measurement tasks since the oscilloscope will trigger on virtually any point of the signal due to the nature of the radar pulse. A pulse width trigger, which can be used to trigger on the interframe time between pulses, is more useful because it allows individual pulses or entire pulse sequences to be detected and analyzed. The trigger condition can be configured for specific radar signal parameters, for example to only display pulses with a specific duration.

See also the "Trigger on radar RF pulses with an oscilloscope" application card:
https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/pdfs/Trigger-on-radar-RF-pulses_ac_en_3609-2000-92_v0100.pdf

Checking the modulation in the radar signal

For the best possible spatial resolution, current automotive radars use bandwidths up to 4 GHz. The R&S®RTP meets the associated T&M requirements. With its high sampling rate and large memory, it captures the downconverted radar signal with a sufficiently high sampling frequency. The analysis tools included in the base configuration are sufficient to check the modulation in the radar signal. The downconverted signal that is used starts at 1 GHz and rises linearly to 5 GHz. An initial check of these frequencies starts with a frequency measurement that is configured to perform many frequency measurements within one acquisition (frequency tracking). The result is a display of the downconverted frequency versus time $f_{IF}(t)$.

At higher frequencies, the data points are closer together, making the measurement more difficult. Noise often increases, but can be filtered out by the oscilloscope's lowpass filter math function. It is possible to change the scaling of $f_{IF}(t)$ (increase the frequency axis) to display the radar signal in its original frequency range $f_{HF}(t)$ (Fig. 3).

Other measurement functions help users quickly determine important parameters such as the rise time of the linear frequency modulation. For example, the oscilloscope's FFT function creates a spectrogram that shows how the radar signal changes over time. These two analysis methods (Figs. 2 and 3) allow users to perform an initial check of the bandwidth and the modulation.

Investigating an FMCW radar signal with the R&S®VSE software's transient analysis function

The R&S®VSE vector signal explorer software offers advanced analysis tools for investigating radar signals, for example to check the linearity of a frequency modulated continuous wave (FMCW) radar signal, which has a large influence on the Doppler properties of a target. The software's R&S®VSE-K60C transient chirp measurements option performs this measurement with high accuracy (Fig. 4). The R&S®VSE-K60C displays the frequency response $f_{IF}(t)$ and calculates the deviation from the ideal linear phase. The software can be installed directly on the oscilloscope or on an external computer. The data is transferred from the oscilloscope to the computer via Ethernet, for example.

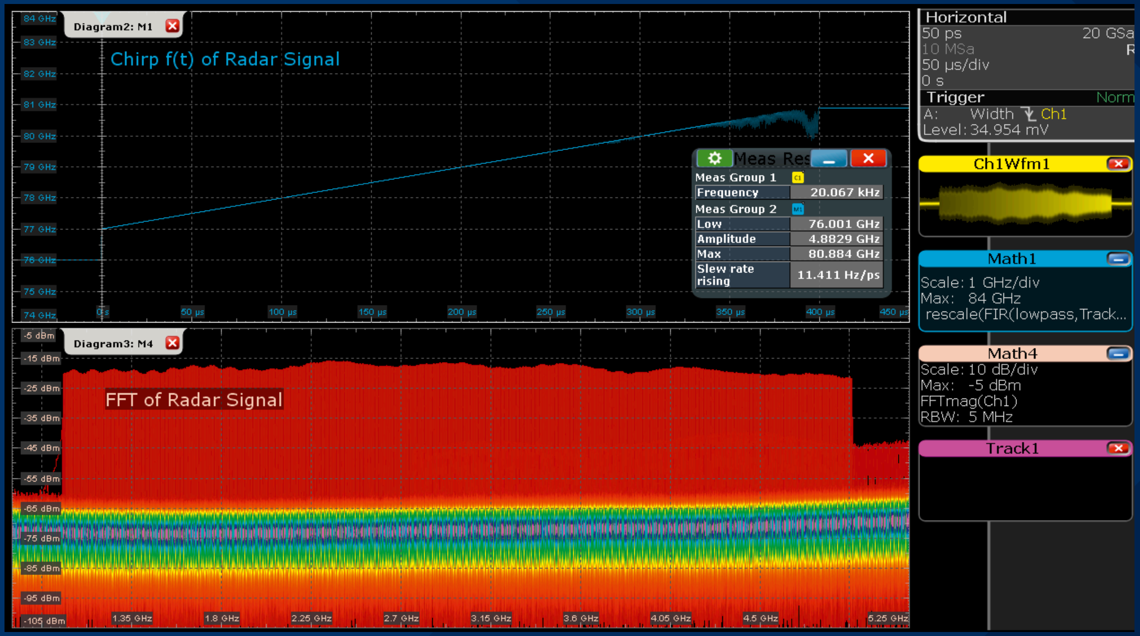


Fig. 3: Top: With suitable scaling and filtering, the radar signal can be displayed in its original frequency range $f_{HF}(t)$. Measurement functions provide important parameters, such as the slew rate of the chirp. Bottom: The FFT shows the power profile of the chirp.

Fig. 4: Transient analysis of a chirp sequence signal with the R&S®VSE-K60C transient chirp measurements option. The pulse power versus time is shown at the top left. The linear frequency response can be seen in the top middle and in the spectrogram on the bottom left. The software lists the properties of the detected pulses in a table (bottom middle). The properties can also be investigated in detail in graphical form. The chirp rate and frequency deviation are shown on the right.

MEASURING PHASE AND AMPLITUDE DIFFERENCES WITH MULTICHANNEL ANALYSIS

Many automotive radars are equipped with multiple transmit and receive antenna arrays. These determine the directivity of the antenna and allow beamforming and detection of the direction of the target. To specifically investigate the transmit properties, for example, multiple mixers can be operated simultaneously on the oscilloscope. The setup is similar to that for single-channel analysis; the LO signal simply has to be distributed to all the mixers (Fig. 1).

Oscilloscope as phase coherent receiver

When used as a phase coherent receiver, the oscilloscope analyzes multiple signals relative to each other. Typically, the phase differences and difference between the two spectra are analyzed. The FFT function of the R&S®RTP is also helpful. It is used to calculate the amplitude spectra of the signals in the two channels. The difference is then calculated with another math function and displayed.

Using FFT to determine phase properties

For the phase measurement, the analysis range is limited to a narrow time corridor, and the phase difference of the two input channels is calculated from the phase properties determined by FFT (Fig. 5).

The advantage of the indirect method using FFT is the larger time analysis range. Whereas a single measurement of the phase difference in the time domain can be strongly dominated by noise, in the frequency domain multiple signal periods are compared with each other, resulting in a significantly smaller measurement uncertainty.

Fig. 5: Multichannel measurement of a chirp sequence. The pulses are shown in the time domain (top), the spectra of the individual channels in the middle, and the amplitudes and phase difference are shown on the bottom left and bottom right, respectively.

DEBUGGING BY CORRELATING RADAR SIGNALS WITH OTHER SIGNALS

Simultaneous acquisition of CAN bus or automotive Ethernet signals together with radar signals

The R&S®RTP oscilloscope can measure the amplitude and phase differences of multiple antenna paths simultaneously and correlate the radar signals with other signals, such as the supply voltage or digital bus signals (Fig. 6). Simultaneously acquiring CAN bus or automotive Ethernet signals together with radar signals is particularly helpful during development and debugging. The analysis time of the radar sensor can be determined from the delay between the radar signal and the bus protocol signal. If the measured delay exceeds a specified time, deployment in autonomous vehicles is not acceptable.

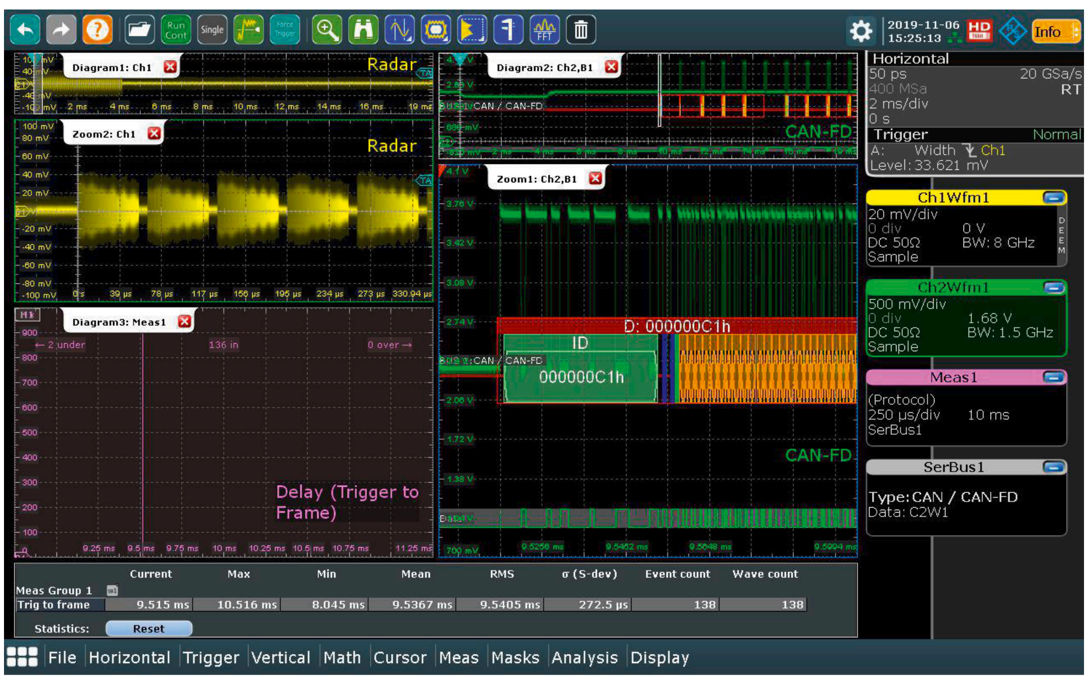
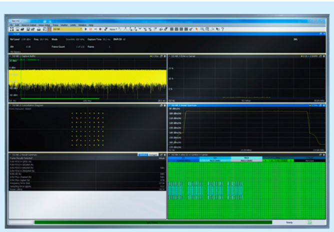


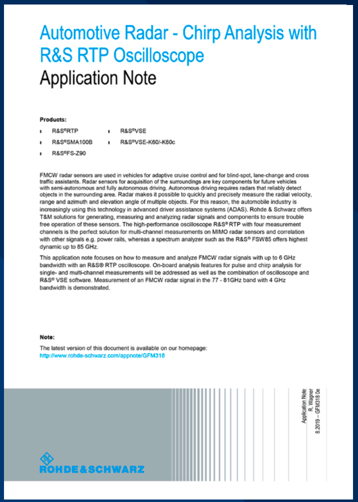
Fig. 6: Measurement of the delay between the radar signal (left) and the CAN protocol frame (right). The oscilloscope triggers on the radar signal and, using the "Trigger to Frame" function, measures a delay of 9.54 ms from when the radar signal is transmitted to when the protocol transfer starts (bottom left).

PORTFOLIO

	Type	Designation	Application
	R&S®RTP064/R&S®RTP084	Oscilloscope	Radar signal analysis on up to four channels
	R&S®SMA100B	Signal generator	Local oscillator source
	R&S®ZV-Z1227	Power splitter	Feeds the LO signal to the two harmonic mixers
	2 × FH-SG-90	E band horn antenna	The horn antenna receives the radar signal
	2 × R&S®FS-Z90	Harmonic mixers	The harmonic mixers downconvert the radar signal is to an IF frequency of 3 GHz
	R&S®RT-ZA17	High-precision, low-loss matched cable pair, length: 1 m	Matched HF cable pair with 3.5 mm plugs on both ends
	R&S®RT-ZA16	Precision BNC to SMA adapter	Adapts SMA connector to BNC connector on the R&S®RTP
	R&S®VSE	Vector signal explorer software	The software's R&S®VSE-K60C transient chirp measurements option analyzes transients with high accuracy

AUTOMOTIVE TEST SOLUTIONS

As a leading global manufacturer of test and measurement equipment, Rohde & Schwarz offers expert know-how for all phases of automotive development – from predevelopment to R&D to production. OEMs, Tier 1s and chip suppliers benefit from the company's reliable solutions for high frequency, high bandwidth and high-speed test challenges. Rohde & Schwarz is the market leader for testing radar sensors, automotive Ethernet conformance, connectivity (5G, V2X, eCall, GNSS), infotainment, EMI precompliance and EMC. The company also offers outstanding solutions for in-circuit and functional testing (ICT/FCT) during ECU production. All of these test solutions will ensure maximum efficiency in compliance with the highest quality standards, assuring that various automotive components function correctly, coexist successfully and communicate with the outside world without errors.


Automotive Radar - Chirp Analysis with R&S RTP Oscilloscope
Application Note

Products:

- R&S®RTP
- R&S®SMA100B
- R&S®FS-Z90
- R&S®VSE
- R&S®VSE-K60/-K60c

FMCW radar sensors are used in vehicles for adaptive cruise control and for blind-spot, lane-change and cross traffic assistants. Radar sensors for acquisition of the surroundings are key components for future vehicles with semi-autonomous and fully autonomous driving. Autonomous driving requires radars that reliably detect objects in the surrounding area. Radar makes it possible to quickly and precisely measure the radial velocity, range and azimuth and elevation angle of multiple objects. For this reason, the automobile industry is increasingly using this technology in advanced driver assistance systems (ADAS). Rohde & Schwarz offers T&M solutions for generating, measuring and analyzing radar signals and components to ensure trouble free operation of these sensors. The high-performance oscilloscope R&S® RTP with four measurement channels is the perfect solution for multi-channel measurements on MIMO radar sensors and correlation with other signals e.g. power rails, whereas a spectrum analyzer such as the R&S® FSW85 offers highest dynamic up to 85 GHz.

This application note focuses on how to measure and analyze FMCW radar signals with up to 6 GHz bandwidth with an R&S® RTP oscilloscope. On-board analysis features for pulse and chirp analysis for single- and multi-channel measurements will be addressed as well as the combination of oscilloscope and R&S® VSE software. Measurement of an FMCW radar signal in the 77 - 81GHz band with 4 GHz bandwidth is demonstrated.

Note:

The latest version of this document is available on our homepage:
http://www.rohde-schwarz.com/appnote/GFM318

Application Note
R. Wagner
8.2019 – GFM318 0e

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Analysis of radar signals is described in detail in the application note "Automotive Radar – Chirp Analysis with R&S®RTP Oscilloscope".

https://www.rohde-schwarz.com/applications/automotive-radar-chirp-analysis-with-r-s-rtp-oscilloscope-application-note_56280-667909.html

https://www.rohde-schwarz.com/video/77-ghz-automotive-radar-part-3-video-detailpage_251220-666562.html

About Rohde & Schwarz
The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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