Application Note

REAL-TIME RAILWAY EMC MEASUREMENTS TO EN 50121

Railway testing made easy with two receivers measuring the magnetic field (150 kHz to 30 MHz) and the electric field (30 MHz to 1 GHz) in parallel

Products:

► R&S®ESW

► R&S®EPL1000

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Contents

1 Standardization

Rolling stock refers to any railway vehicle that moves exclusively on rails or a tracked transport system. The term includes all powered (e.g. locomotives) and unpowered vehicles like passenger carriages or goods wagons. Rolling stock testing covers physical testing of rail vehicles and components to ensure they meet safety, performance, and regulatory standards. Trains and other rolling stocks are tested on the track at a drive test as it is not practical to fit these test objects into an anechoic chamber.

EN 50121 standard ensures the electromagnetic compatibility of railway equipment. Signaling infrastructure, train stations or anything else alongside the tracks must be protected from malfunctioning from the train's emission. As modern railway equipment facilitates many built-in electronic components, working at high clock rates, the need for testing is rising although the main cause for emission, the electric drive train, is not new for the industry.

The subpart EN 50121-3-1 defines the emission measurement methods and its corresponding limits between 150 kHz to 30 MHz measuring the magnetic field and from 30 MHz to 1 GHz measuring the electric field. At least two antennas are required, a loop antenna for the magnetic field and e.g. a log-periodic antenna for the electric field. The antennas must be placed at 10 m distance from the center of the train tracks at a position that allows repeatability with a minimum of surrounding ambient interferers and other obstacles. With power line masts present, a position must be found in the middle between two. Measured from the top of the train tracks, the loop antenna must be placed in 1 m to 2 m height to its reference point. For the electric field antenna, the height shall be 2.5 m to 3.5 m. If the ground floor, the antennas are standing on, deviates by more than 0.5 m from the surface of the train tracks, this height deviation must be documented in the test report. All dimensions are given in Figure 2 and Figure 3.

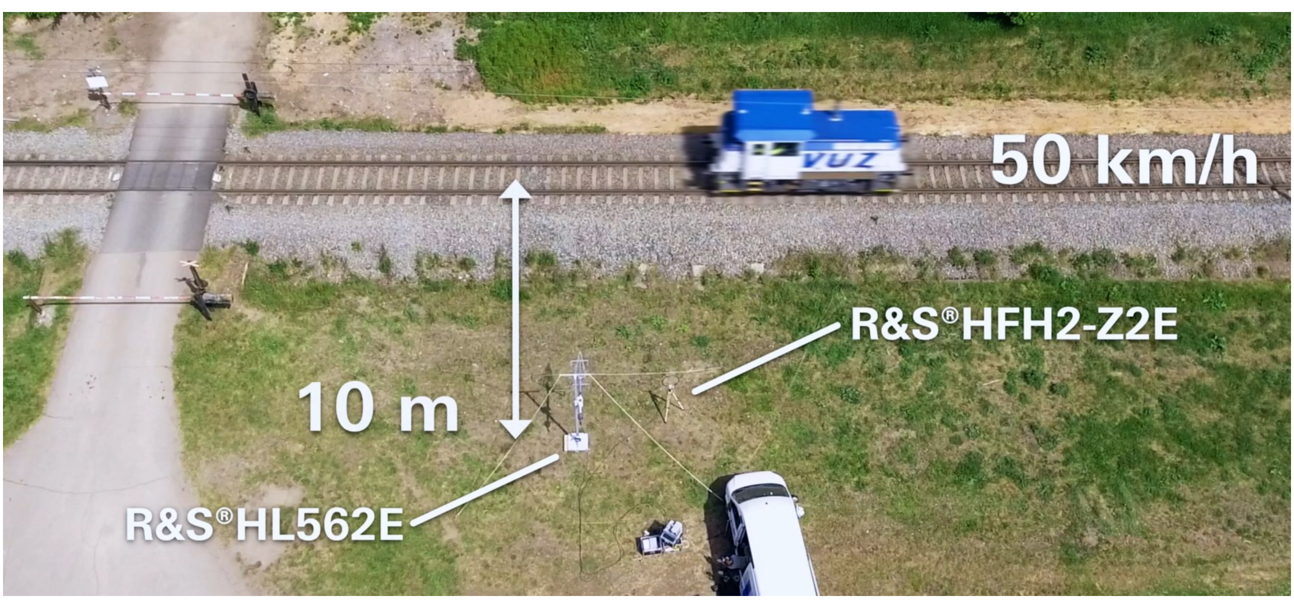

Figure 1 Test setup with magnetic loop antenna R&S®HFH2-Z2E and log-periodic antenna R&S®HL562E in 10 m distance.

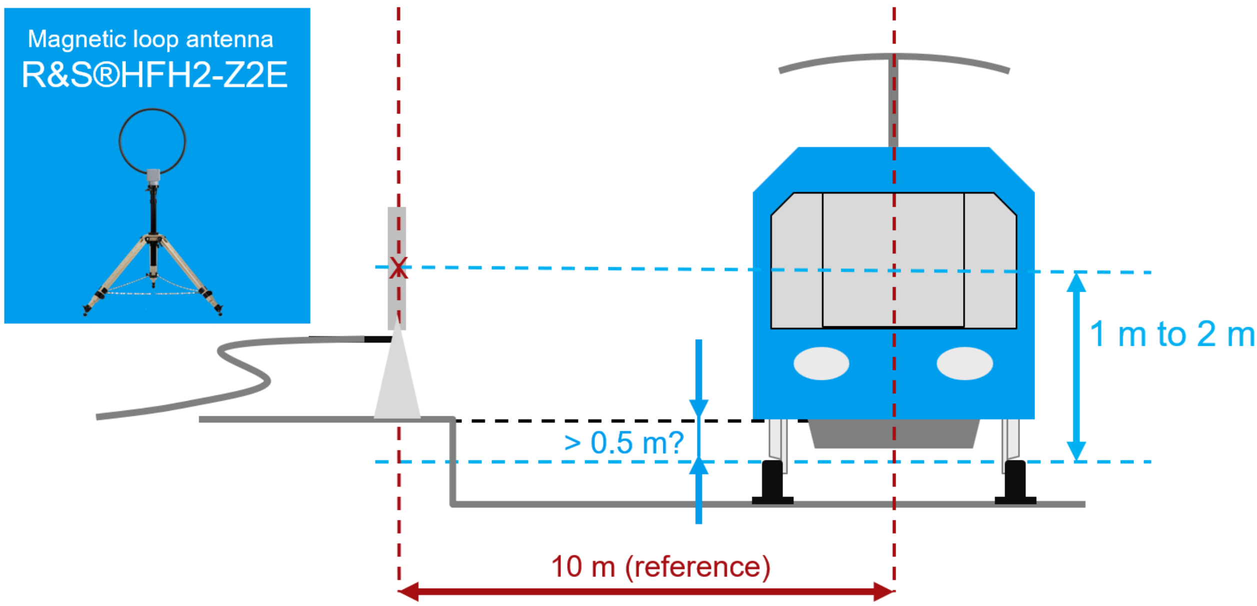

Figure 2 Setup for magnetic field measurement with loop antenna from 150 kHz to 30 MHz. Documentation is needed if the antenna ground deviates by more than 0.5 m from the upper surface of the tracks.

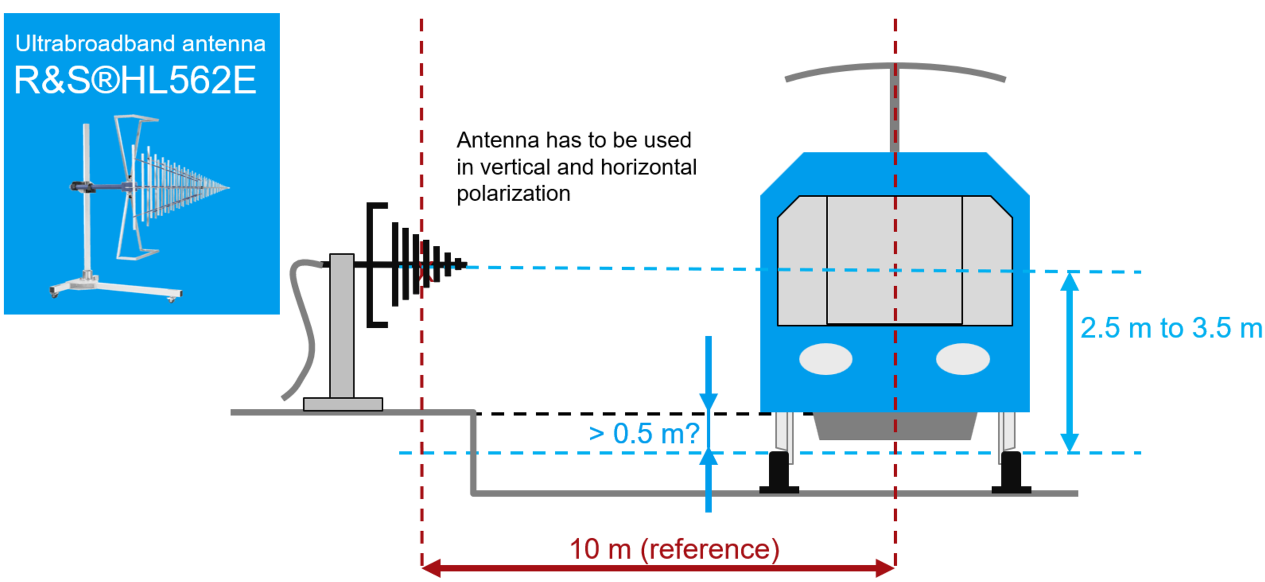

Figure 3 Setup for electric field measurement with ultrabroadband antenna from 30 MHz to 1 GHz. Documentation is needed if the antenna ground deviates by more than 0.5 m from the upper surface of the tracks.

2 Railway rolling stock test

Two independent setups are used to parallelize the measurement and to minimize the rolling stock and test track operating time. With both the magnetic field and electric field measured in just a single measurement each and those two in parallel with two independent setups, only a single measurement of the moving rolling stock is needed.

The magnetic loop antenna R&S®HFH2-Z2E captures the range from 150 kHz to 30 MHz, connected to an R&S®EPL1000 EMI test receiver. The test receiver covers the frequency range until 30 MHz, making it the right instrument at an affordable price while offering full CISPR 16-1-1 compliance. Its small size and weight, the battery power option and the capability of measuring the required CISPR band B (150 kHz to 30 MHz) in a single FFT shot in real-time make it ideal for the purpose.

The high-end EMI test receiver R&S®ESW equipped with the B1000R wideband extension captures the electric field in CISPR band C and D (30 MHz to 1 GHz) using the log-periodic antenna R&S®HL562E. With 970 MHz real-time bandwidth, this instrument allows accurate measurements with just one single FFT segment. Despite the large FFT bandwidth, the R&S®ESW allows accurate measurements with highest dynamic range due to narrow frequency selectivity enabled by sophisticated analog preselection filter design.

Test	Antenna		Receiver
Magnetic field 150 kHz - 30 MHz	**R&S®HFH2-Z2E** Broadband active loop antenna for measuring magnetic field strength from 8.3 kHz to 30 MHz		**R&S®EPL1000** Compliance testing up to 30 MHz enabling real-time spectrogram for the magnetic field band with CISPR detectors 
Electric field 30 MHz - 1 GHz	**R&S®HL562E** Ultrabroadband antenna for EMI and EMS applications combines the characteristics of biconical and log-periodic antennas from 30 MHz to 8 GHz		**R&S®ESW with B1000R** High-end compliance testing up to 44 GHz with the highest speed, widest bandwidth and greatest sensitivity. With wideband extension B1000R it enables real-time spectrogram with CISPR detectors for the full range of 30 MHz to 1 GHz 

2.1 Measurement procedure

At first, the rolling stock under test stands still in front of the antennas with all systems turned off to allow a reference measurement of the environment. The ambient emission is tested using a quasi-peak detector. A long measurement time of 15 s achieves a reliable representation of the ambient emission. As the test is not done in a shielded environment, radio carriers, interferences from other surrounding devices and many other effects show a noisy ambient spectrum. The train with all systems turned off can even influence the radio environment by reflecting emission from elsewhere. The challenge of in-situ (at the place of operation) tests is to distinguish between ambient and DUT emission. EN 50121-3-1 defines a simple procedure: All emissions exceeding the limits found in the ambient test are suppressed in the final drive test.

Real-time FFT receivers

With the two receivers capturing the two bands in only one FFT bandwidth each, the ambient measurement is completed in a short time despite the long measurement time of 15 s. To achieve such a wide bandwidth at a high dynamic range with real-time processing, a sophisticated preselection concept reduces the spectral energy the instrument sees to get the noise floor down for more sensitive measurement results. Fast FFT processing using strong FPGAs helps to calculate the spectral components from the samples in time domain the analog-to-digital-converter (ADC) sample at highest bit rates.

The limits for the quasi-peak measurement are given in standard EN 50121-3-1. Those frequencies that are found in the ambient test to be above the limit lines or within 6 dB margin can be ignored in the drive test. The same ambient measurement must be repeated at the very end of the test campaign and both ambient tests combined are used for the evaluation of frequencies to be ignored.

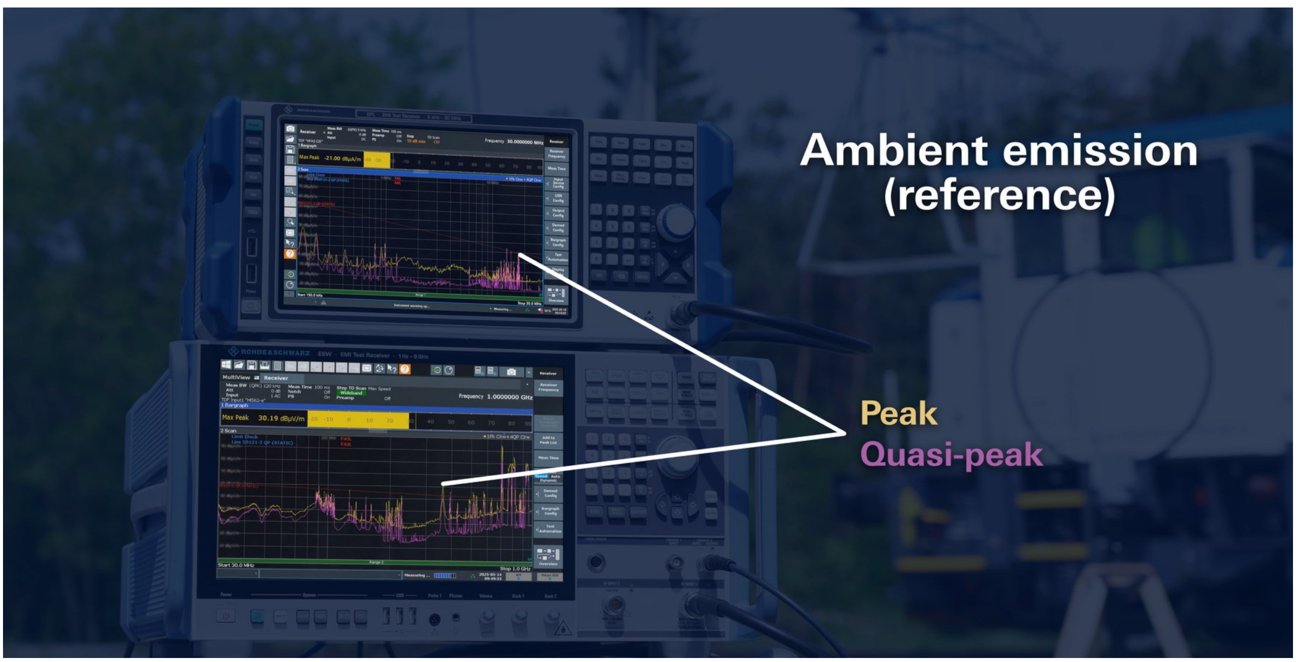

Figure 4 Reference measurement of the ambient emission using quasi-peak and additional peak detector.

Measurements of the rolling stock are required in stand still with all systems turned on and in drive mode at (50 ± 10) km/h with the railcar either accelerating or braking. The stand still test uses the quasi-peak detector and the corresponding limit lines while the rolling stock driving test uses the peak detector and a different limit line. On conventional receivers, the quasi-peak detector will slow down tests due to time constants, minimum required measurement times and waiting for the instrument to settle, thereby preventing tests of a fast-moving train or rolling stock. With modern fast receivers as the R&S®ESW, such tests are made possible with an FFT bandwidth so large, that it captures the complete required span from 30 MHz to 1 GHz in just a single FFT segment. This avoids scanning across multiple segments or unnecessary waiting for filters to settle to achieve fastest measurements.

2.2 Real-time analysis

Since both instruments, the R&S®EPL1000 and the R&S®ESW equipped with B1000R wideband extension, can measure the full required band (for EN 50121-3-1 standard) in just a single shot, they can continue that measurement over and over for a long time to display a spectrogram. The spectrogram ("waterfall") display is real-time with no gaps in between consecutive measurements. See the results in Figure 6 below where each horizontal line in the spectrogram represents one scan trace, with the current scan trace displayed on the upper display. While one trace is captured in a single segment (here the full bandwidth of either magnetic or electric field) for the duration of the selected measurement time (e.g. 1 second), the receiver processes the spectrum data including the detector calculation simultaneously. This allows timing analysis and shows precisely at what time, amplitude, frequency and how long any emission occurred.

Figure 5 Start of measurement triggered using a light barrier.

Real-time measurements give the operator all the flexibility without the need for precise timing, light barriers aren't required but still come in handy on triggering the start of the real-time spectrogram measurement.

3 Test results

Generally, despite its remote location, many radio services were seen at the test site such as analog FM and digital DAB radio, cellular providers and many other services. The spectrogram plots of both receivers (see Figure 6 R&S®ESW scan and spectrogram display showing the train drive test emission using peak detector for the electric field. The limit line check in the scan display indicates a fail of the test as ambient emission is already above the limit.Figure 6 and Figure 7) show clearly the influence of the rolling stock passing by with emissions from the rolling stock (e.g. around 350 MHz, yellow arrow) or side effects as a radio reflector (GSM amplitudes fluctuating, red arrow). According to EN 50121-3-1 standard, those frequencies identified in the ambient analysis above the limit lines, are not tested in the drive test. However, these need to be documented in the report.

Both spectrograms below were captured with just one single passage of the rolling stock. Ideally, one measurement can test a complete train including all railway cars. This speed improvement shows significant advantages for the test procedure, not only in time and effort, but also in reliability and the overall analysis capabilities.

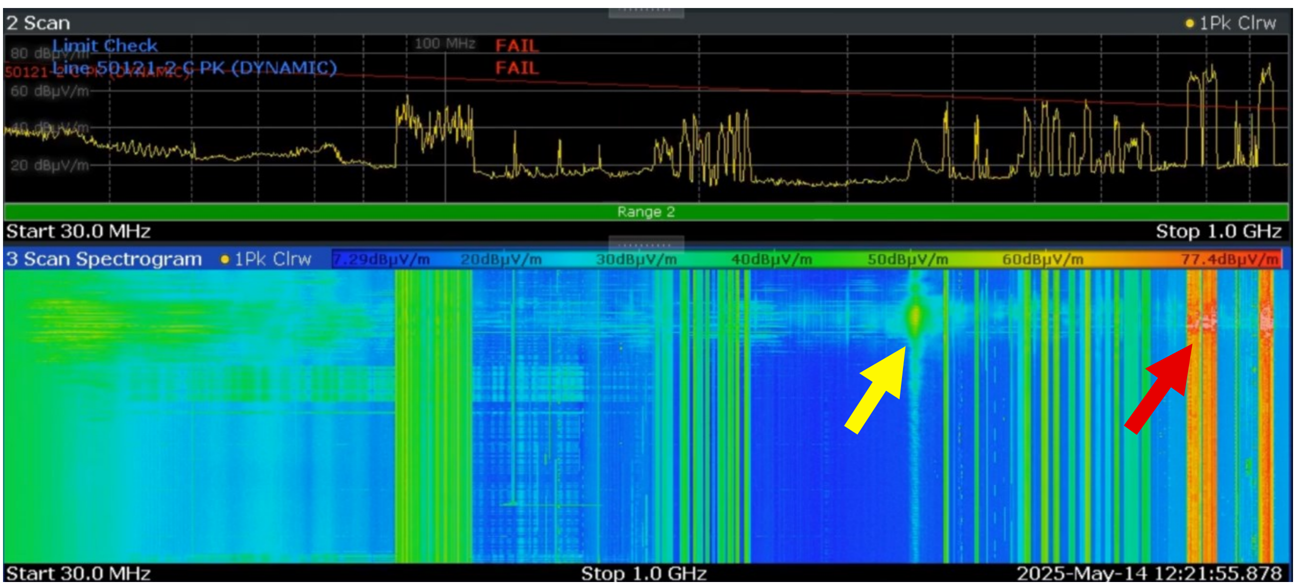

Figure 6 R&S®ESW scan and spectrogram display showing the train drive test emission using peak detector for the electric field. The limit line check in the scan display indicates a fail of the test as ambient emission is already above the limit.

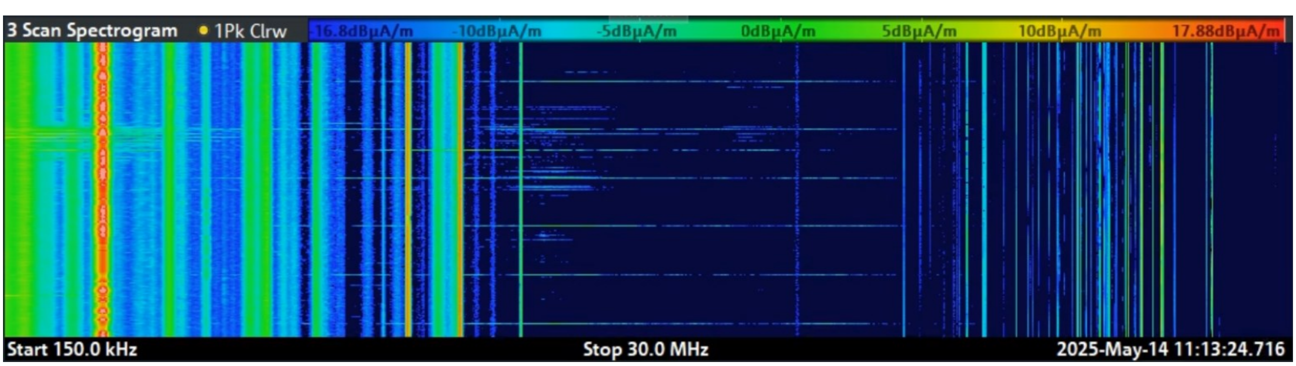

Figure 7 R&S®EPL1000 spectrogram display for the train drive test emission using peak detector for the magnetic field.

4 Test automation in R&S®ELEKTRA

The R&S®ELEKTRA test software controls complete EMC systems and automates measurements of equipment under test (EUT) being certified for emissions (EMI) and immunity (EMS). The software simplifies configuration of test systems and test descriptions in accordance with common standards as the EN 50121-3-1 for railway testing.

The measurement procedure described in Section 2.1 consists of four steps.

1) An ambient test is performed prior to the field test to identify frequencies that can be excluded from the evaluation of field test results. Subsequently, the limit line defined by EN 50121-3-1 is updated by introducing notches at the excluded frequencies.
2) A field test, applying the updated limit line created in Step 1 is performed.
3) A second ambient test is performed, and the limit line updated in Step 1 is further modified in the same manner.
4) Re-evaluation of the field test performed in Step 2 using the updated limit line from Step 3

The four-step procedure described above can be automated within the R&S®ELEKTRA software using Python scripts with the R&S®ELEMC-RHAP – Hosted Application Runtime Extension option. The automation includes launching the test, executing the measurements, saving the results, updating the limit lines, and re-evaluating the test data with updated limit lines as required in specific steps.

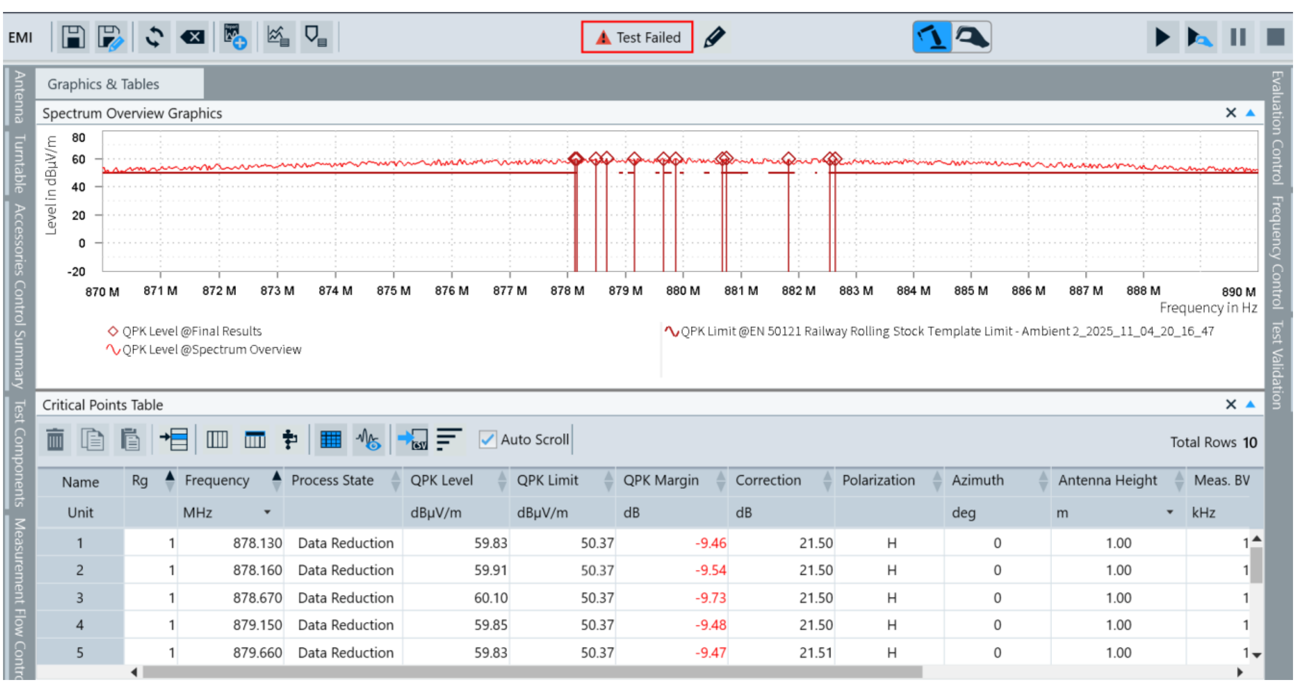

Figure 8 Test view in R&S®ELEKTRA: Zoomed section of test showing gaps in the limit where ambient signals exceeded the limit. These critical points that are blanked out in the final test are listed in the table below.

To learn more about Rohde & Schwarz innovative EMI test receivers, the EMC automation software and other EMC test solutions, please visit – "[EMC testing | Rohde & Schwarz]"

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Application Note | Real-time railway EMC measurements to EN 50121
Data without tolerance limits is not binding | Subject to change