Comparison of Time Domain Scans and Stepped Frequency Scans in EMI Test Receivers

Products:

- R&S®ESR3
- R&S®ESR7
- R&S®ESR26

Taking the R&S ESR EMI test receiver as an example, this paper looks at a CISPR 16-1-1-compliant test instrument with time domain scanning capabilities. The paper compares the measurement speed and level measurement accuracy of a conventional stepped frequency scan versus an advanced FFT-based time domain scan. It also contains guidance on making optimum use of time domain scans.

Whitepaper

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ROHDE&SCHWARZ

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1 Motivation

During product development, the frequency spectra of disturbances need to be measured frequently and compared against the limits set in current product standards. The effectiveness of the instrument's shielding is checked by an EMC engineer. Being able to have the measurement results available quickly streamlines efforts to shield the instrument efficiently and reduces the time to market. The introduction of spectrum measurements based on fast Fourier transform (FFT) – also known as a time domain scan – allows a significant reduction in measurement times without affecting accuracy. The CISPR, the International Special Committee on Radio Interference, has embraced this new technology: As of the publication in June 2010 of Amendment 1 to the third edition of CISPR 16-1-1, the use of FFT-based test instruments is permitted in standard-compliant measurements.

Rohde & Schwarz launched with the R&S ESU the world's first commercial EMI test receiver capable of time domain scans. The EMI test receiver family R&S ESR does also support time domain scans and delivers even faster measurements.

Taking the R&S ESR EMI test receiver as an example, this paper examines a CISPR 16-1-1-compliant test instrument with time domain scanning capabilities. It compares the measurement speed and level measurement accuracy of conventional stepped frequency scanning (the reference) against the speed and accuracy of advanced time domain scanning. It also contains guidance on making optimum use of time domain scans.

2 How an FFT-Based Test Receiver Operates

2.1 A Classic Test Receiver

A classic test receiver converts its input signal through a number of intermediate frequencies. At the final intermediate frequency (IF), IF filters limit the signal to the desired measurement bandwidth – 9 kHz, for example. The IF is rectified to produce a video voltage representing the signal level versus time. This video voltage is sent to the detector circuits. The detectors deliver standard-compliant, weighted measurement results at their outputs: the peak value, average value, quasi-peak value, etc. In early-model, partly digital test receivers, the A/D converter replaces the analog display instrument at this point, marking the transition from analog to digital signal processing in the signal path. With this arrangement, the test receiver can only show the signal level within the measurement bandwidth. When measuring a frequency spectrum from, say, 30 MHz to 1 GHz, the only option is to tune the receive frequency in steps that are smaller than the measurement bandwidth and to compile the spectrum from a series of individually conducted measurements.

Advanced test receivers, by contrast, digitize the IF. The IF filters, rectifiers and detectors – formerly analog parts of the circuitry – are fully digital. The A/D converter is of particular importance: Its characteristics determine the maximum IF measurement bandwidth and possible dynamic range. However, even with this technology, a receiver can only perform measurements within the measurement bandwidth, and measuring a spectrum takes an correspondingly long time.

2.2 A Test Receiver with Digital Signal Processing

An FFT-based test receiver goes a step further. It digitizes the signal mixed onto the intermediate frequency before the signal is limited to the chosen IF bandwidth. The availability of A/D converters with a high sampling rate and a wide dynamic range makes this possible. The latter is not just applied together with the measured signal within the IF bandwidth but, depending on the bandwidth before the A/D converter (pre-A/D), together with the sum signal within "n" bandwidths, where "n" is the ratio of the pre-A/D converter bandwidth to the selected IF bandwidth. The receiver uses fast Fourier transform (FFT) to compute the relevant spectrum from the time domain signal of the digitized IF. The IF contains the spectrum to be measured in the time domain – hence the term "time domain scan". The FFT parameters and the time domain signal window are set in such a way that the resolution bandwidth and filter characteristics match the IF bandwidths stipulated in CISPR16-1-1. In this way, the receiver implements a filter bank with, say, several thousand parallel filters. After each of these filters there are a rectifier and detectors. Instead of a single measured value representing the frequency range of each measurement bandwidth (e.g. 9 kHz), this approach delivers a large number of parallel measured values covering the frequency range of several thousand measurement bandwidths at the same time. This reduces the measurement time by a factor that corresponds to the number of parallel measurement bandwidths.

The R&S ESR EMI test receiver's A/D converter delivers raw data at a data rate of 128 MHz. The dynamic range of level measurements for pulsed signals is determined by the combination of preselection and the A/D converter. The purpose of preselection is to reduce the peak pulse voltage through band limitation and so avoid overloading any mixers, IF amplifiers or the A/D converter. The receiver's converter and digital signal processing operate at a resolution of 16 bits and thus have so much dynamic range that the preselection filters can be much wider than in earlier generations of instruments and do not limit the overall dynamic range. This is important in order to allow the instrument to compute the FFT over as large a frequency range as possible.

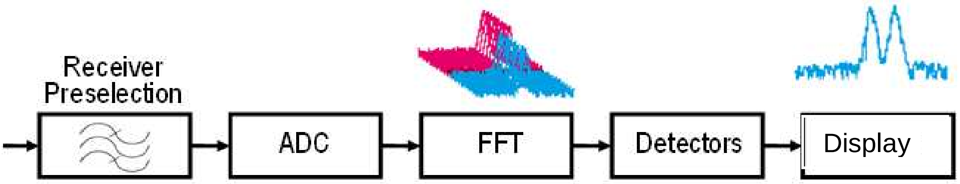


Fig. 1: Processing chain for the FFT-based time domain scan.

In the next stage, the digital downconverter reduces the data rate to match the measurement bandwidth – 30 MHz at most. Then, the signal processing carries out the FFT computations and returns the frequency spectra. Depending on the instrument settings (the measurement bandwidth, for example), the FFT can be up to 16 384 frequency bins in length (16k-FFT). This FFT length and the wide preselection make it possible to capture the whole of CISPR band B, from 150 kHz to 30 MHz, at the standard-compliant measurement bandwidth of 9 kHz.

The test specifications (i.e. standards) require different detectors when evaluating disturbance signals – peak value and average value detectors, and more complex quasi-peak, CISPR-average and RMS-average detectors, for example. In classic receivers, after band limitation, the video voltage is sent through the IF filter (e.g. 9 kHz or 120 kHz) into the detector circuit. A current, classic EMI test receiver can operate multiple parallel detectors and display them at the same time, but only for a single frequency. An FFT-based test receiver computes a large number of FFTs and therefore spectra during the configured measurement time. The digital detector circuit first puts the frequency spectra more or less in series and generates up to 16 384 video voltages on neighboring frequencies. The receiver analyzes each of these video voltages with the same number of parallel detectors and, after the set measurement time, returns not just one level value but several thousand. Even highly complex signal analyses like quasi-peak detection, which involves different charge and discharge time constants and a second-order lowpass filter, have been implemented using this parallel processing model.

A field programmable gate array (FPGA) provides the requisite computing power. The entire processing chain, from the A/D converter to the detectors, is set up in such a way that all the computing operations can be performed in realtime. This means that the measurement results are shown on the display after a measurement time of, say, one second, but in contrast to a classic test receiver, an FFT-based test receiver can do this for multiple frequencies at once rather than just for a single frequency.

2.3 The Window Function

The Fourier transformation is a mathematical method that provides a simple means of breaking down into frequency components a signal that varies versus time. It uses the Fourier integral to compute the frequency spectrum from a time domain signal. Because the Fourier integral's integration boundaries extend from minus infinity to plus infinity, the observation period is, in theory, infinite. In practice, the fast Fourier transform (FFT for short) is applied. The FFT is computed with a defined number of discrete values and therefore covers a limited time. The duration of signals to be measured and the FFT length generally do not match, because the signals observed are mixed, consisting of periodic, nonperiodic and noise components. The FFT extracts part of the time signal in such a way that jumps occur in the signal at the beginning and end of the FFT. This results in significant quantities of signal components that are not part of the actual spectrum. The occurrence of these side lobes in the spectrum is referred to as leakage.

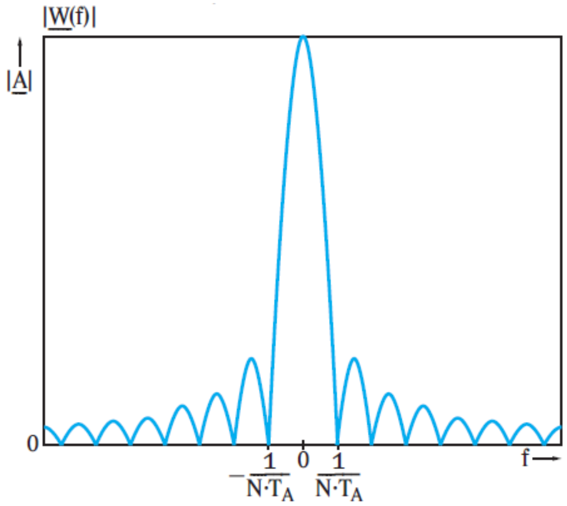


Fig. 2: Spectral diagram of leakage caused by time limitation of the signal.

This is remedied by applying a window function to the samples in the time domain that shows and hides the signal at the beginning and end of the FFT. The signal is periodized, diminishing the side lobes to the extent that they no longer play a role.

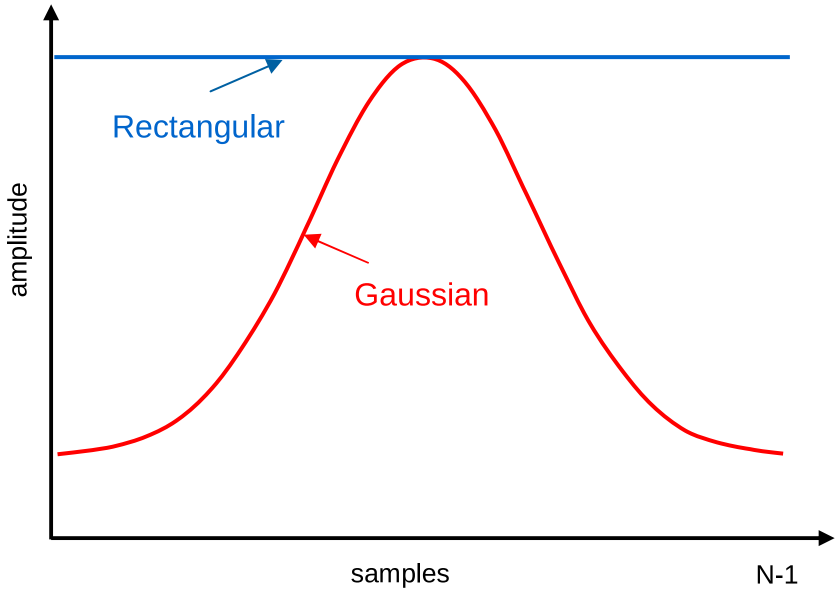


Fig. 3: Rectangular and Gaussian windows.

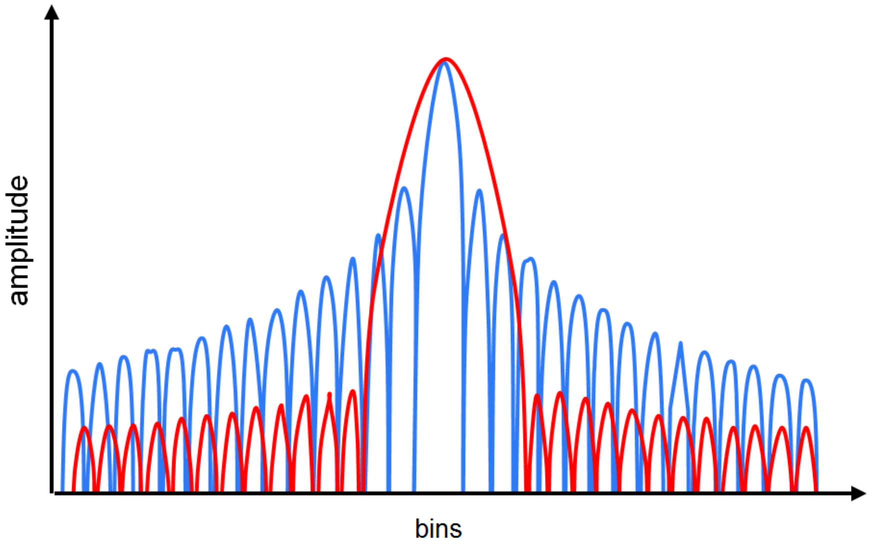


Fig. 4: Blue indicates strong leakage (rectangular window) with a large number of side lobes, red shows leakage greatly reduced by the Gaussian window function.

The window function selected in the time domain defines the filter shape of the measurement bandwidth in the frequency range. The standard applied (CISPR 16-1-1, for example) determines the shape of filter to be used.

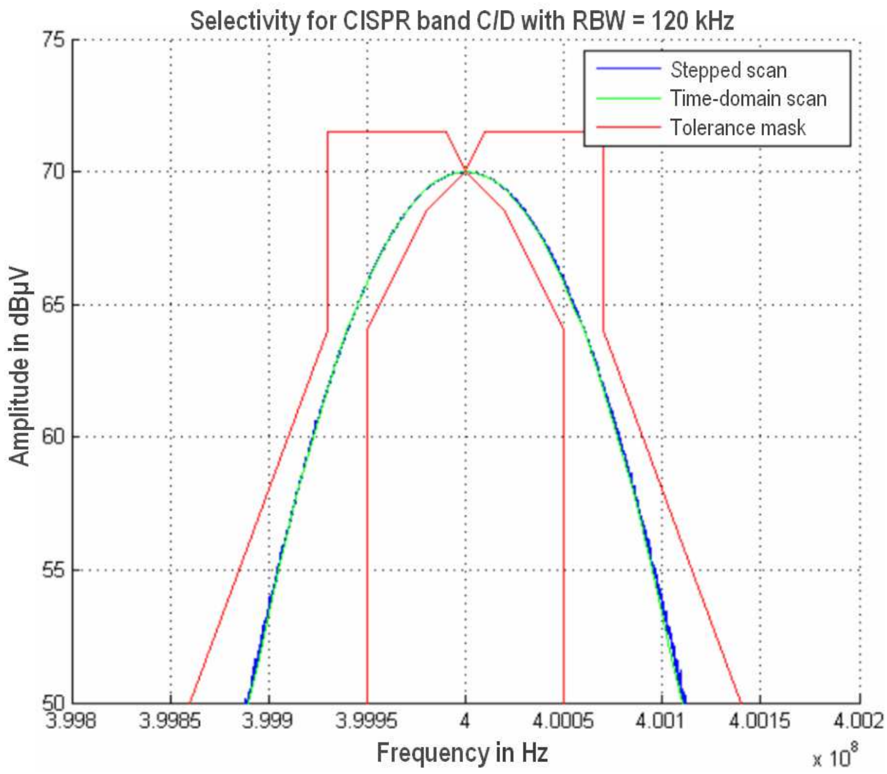


Fig. 5: Tolerance mask as per CISPR for a measurement bandwidth of 120 kHz, and the EMI test receiver's filter shapes.

The R&S ESR multiplies the samples in the time domain with a Gaussian window. This has two advantages: The leakage is suppressed, and the FFT computation produces Gaussian measurement bandwidths (see section 2.4) that exactly fit the tolerance masks defined in the standard.

2.4 Overlapping in the Time Domain

The window function is multiplied with the samples in the time domain as described in the prior section. Brief events (i.e. pulses) are only mapped correctly by a single FFT if they lie in the middle of the window. The window function weakens the signal at the edges.

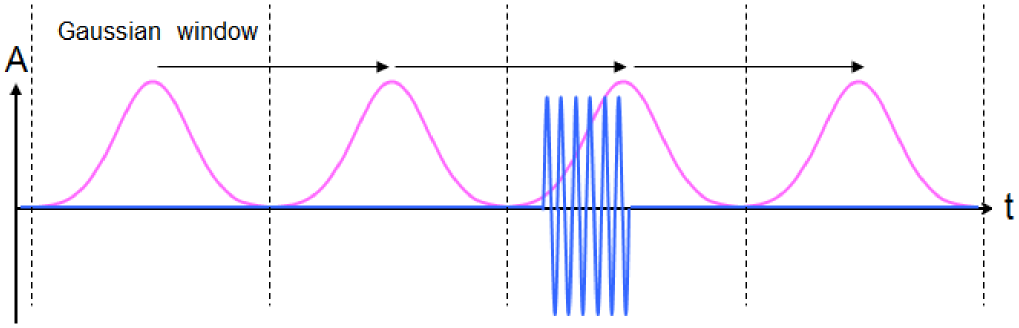


Fig. 6: The window function weakens the pulse at the edge.

The solution is to compute a large number of FFTs while shifting the window by a small percentage of its length between one FFT and the next (short-time FFT).

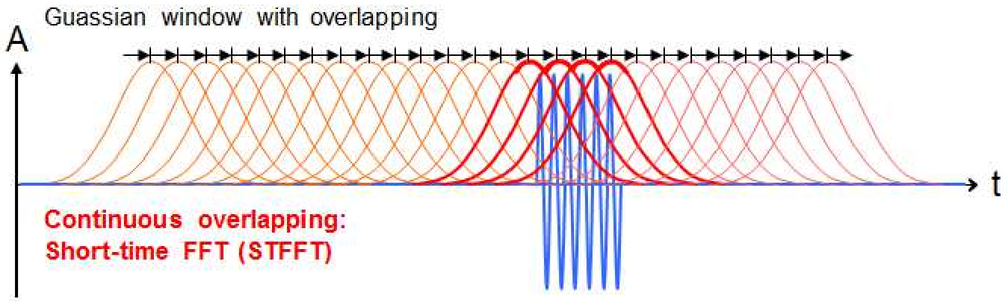


Fig. 7: The short-time FFT (STFFT) consists of highly overlapping FFTs. The level is indicated correctly by the combined FFTs shown in red.

CISPR 16-1-1 requires an overlap of more than 75 % between the FFTs to ensure that the level measurement uncertainty for the pulse amplitude remains less than +- 1.5 dB. In the R&S ESR, the FFTs overlap by at least 93 %. The maximum level error is 0.4 dB and the average level error just 0.1 dB. The detectors after the FFT evaluate all the computed spectra and therefore record the correct level for even the shortest of pulses. The residual level errors resulting from the curvature of the window are so small as to be negligible.

2.5 Overlapping in the Frequency Domain

In the time domain, the Gaussian window function is transformed by the FFT into a Gaussian measurement bandwidth. This produces discrete, overlapping measurement bandwidths in the frequency range. If a sinewave carrier is located exactly between two of these measurement bandwidths referred to as frequency bins, the result is a level error.

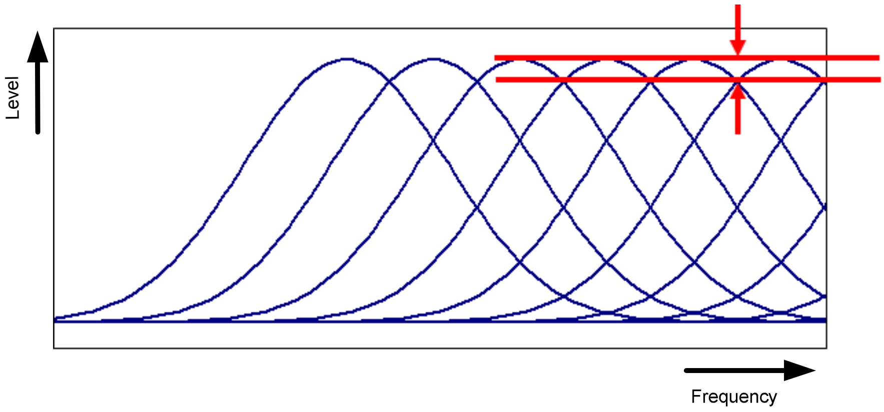


Fig. 8: The picket fence effect. In the frequency domain, too, the level error depends on the overlap.

The R&S ESR has a spacing between adjacent frequency bins of a quarter of the 6 dB measurement bandwidth – that is, 30 kHz at a measurement bandwidth of 120 kHz. The narrow spacing between bins reduces the level error to a maximum of 0.4 dB. In a classic test receiver using stepped frequency scans, the picket fence effect occurs in the same way because this receiver type, too, conducts measurements with discrete frequency spacings. The FFT-based method, however, has an advantage because, in spite of the spacing of a quarter of the measurement bandwidth, which is prescribed to ensure a smaller measurement error, the measurement time remains short. The classic test receiver, by contrast, has conflicting objectives. It may be capable of increasing the step size to half or even the whole of a measurement bandwidth and reducing the number of individual measurements (and, therefore, the overall measurement time, too) but this can only be accomplished at the expense of a much greater measurement error with narrowband disturbance signals. Broadband disturbance signals are generally not affected by this issue because the signal power is distributed so evenly across the spectrum that the highest level is found.

The narrow spacing of the measurement bandwidths naturally means more measured values, so the receiver needs to have sufficient memory capacity to record the results. The R&S ESR can store 4 million level values for each detector measured. With a measurement bandwidth of 10 kHz and a resulting offset of 2.25 kHz, this is sufficient for a frequency range of 10 GHz.

2.6 Detectors

A frequency bin represents the measurement bandwidth of an FFT frequency. The frequency bin is observed versus time, across a large number of FFTs issuing from the FFT block shown in Fig. 1. The level versus time corresponds to the video voltage present in the classic test receiver after the IF filter and rectifier. The big advantage of the FFT-based method is that it delivers a very large number of video voltages at the same time by lining up the FFT-computed spectra. The measurement bandwidth of each frequency bin in the FFT corresponds to the IF bandwidth in the classic receiver. The FFT works like multiple IF filters arranged next one another in the frequency range. The classic receiver feeds the video voltage to the detector circuit directly. Similarly, the FFT-based receiver feeds multiple video voltages at once to a large number of digital detector circuits.

The way the EMI test receiver's peak detector is set up is simple: It stores the highest value of the video voltage during the measurement time. All this requires is a controller and a memory location for the level value of each frequency. The weighting detectors as set out in the CISPR 16-1-1 standard – quasi-peak, CISPR-average and RMS-average – are significantly more complex and compute-intensive. The charge and discharge time constants and the meter time constant are implemented by means of multistage filter functions; they call for a large amount of memory. One of the design goals with the R&S ESR was not just to perform measurements on a large number of frequencies in parallel, but to have the capacity to do so in realtime. To accomplish this, it also has parallel filter functions and detectors.

3 Performance Comparison

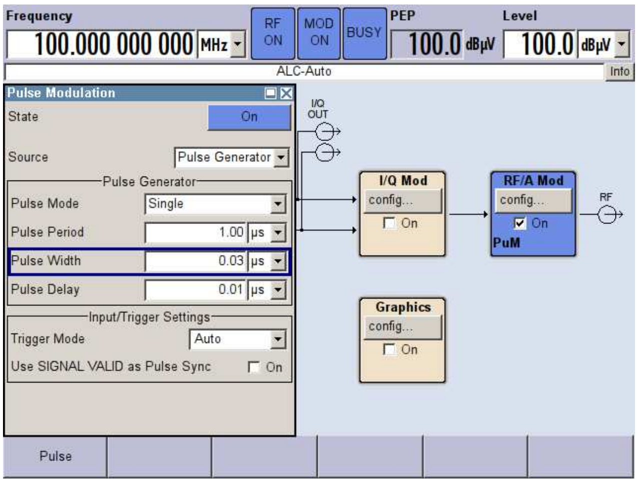
3.1 Comparison of Level Measurement Accuracy

Each CISPR 16-1-1-compliant Rohde & Schwarz EMI test receiver undergoes a compliance test before it ships. One of the purposes of this test is to verify the absolute accuracy and the weighting curves of the CISPR detectors: quasi-peak, CISPR-average and RMS-average. Both the bargraph measurement and the time domain scan are assessed for multiple frequencies. The test signal is supplied by a CISPR-compliant pulse generator. An individual calibration report is issued for each receiver. This means that users can rely on their test receiver complying with the measurement accuracy specified in the data sheet in any operating mode.

For the purposes of this paper, classic stepped frequency scanning and the FFT-based approach are compared in detail to obtain a more accurate assessment of FFT-based time domain scanning. In the test setup, a signal generator supplies a pulse-modulated carrier. The receiver measures the spectrum of the pulsed carrier with various detectors and in various frequency ranges, using both classic stepped scanning and FFT-based time domain scanning. The measurement results are then compared.

3.1.1 CISPR Band C, Peak Detector

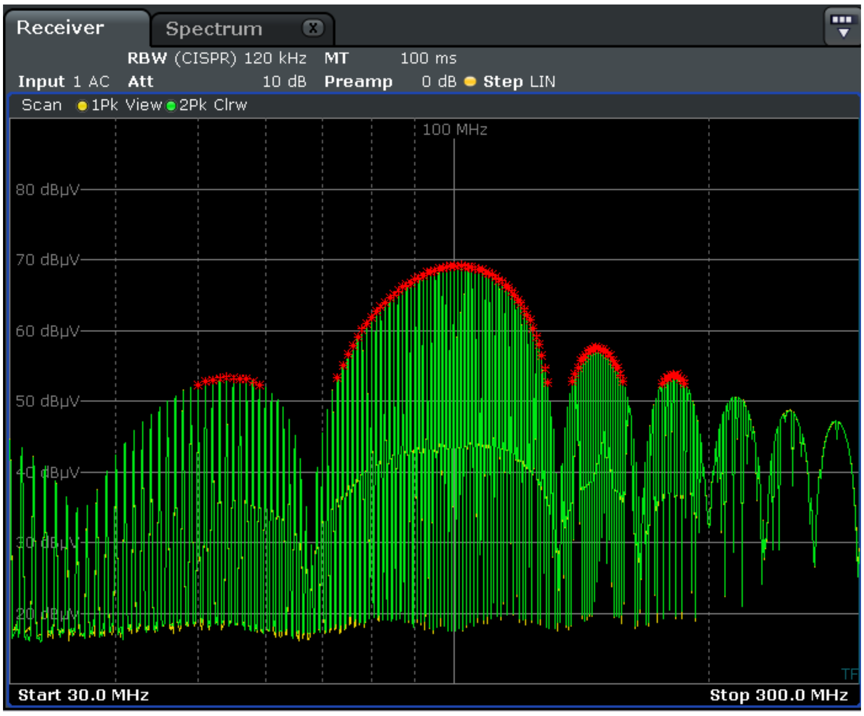
A signal generator with stable levels and frequencies serve as a signal source. A real device under test – a switching power supply, for example – would not be sufficiently stable during an overall measurement time of several hours, and the results obtained would therefore not be truly comparable.


Frequency 100.000 000 000 MHz
PEP 100.0 dBµV
Level 100.0 dBµV
ALC-Auto

Pulse Modulation
State On
Source Pulse Generator
Pulse Generator
Pulse Mode Single
Pulse Period 1.00 µs
Pulse Width 0.03 µs
Pulse Delay 0.01 µs
Input/Trigger Settings
Trigger Mode Auto
Use SIGNAL VALID as Pulse Sync ☐ On

Fig. 9: Settings on the R&S SMBV100A vector signal generator: pulse-modulated carrier at 100 MHz; 1.00 µs pulse duration; 0.03 µs pulse width.

The receiver conducts measurements with a bandwidth of 120 kHz and a measurement time of 10 ms in the frequency range from 30 MHz to 300 MHz; a peak detector is used.

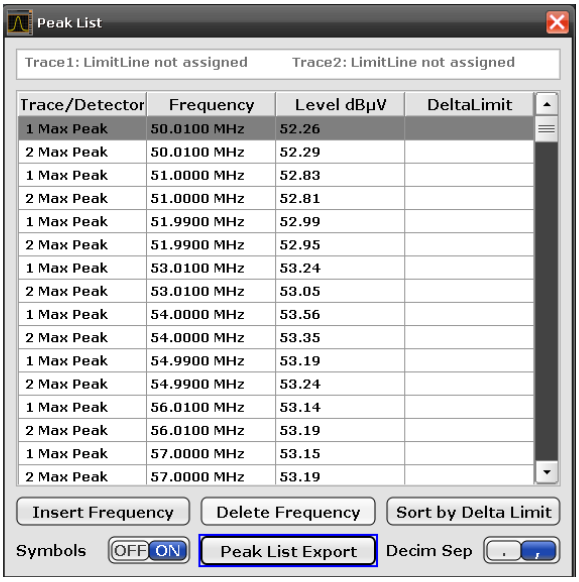


RBW (CISPR) 120 kHz MT 100 ms
Input 1 AC Att 10 dB Preamp 0 dB Step LIN

Start 30.0 MHz Stop 300.0 MHz

Fig. 10: Signal spectra measured; peak detector; 30 MHz to 300 MHz.

Trace 1 (yellow) was measured with a time domain scan, trace 2 (green) with a stepped scan. The two traces map to one another almost exactly. For the detailed analysis, the receiver's peak search function scans each trace for the 100 highest level values. These are indicated by red symbols in the diagram.



Trace1: LimitLine not assigned Trace2: LimitLine not assigned

Trace/Detector	Frequency	Level dBµV	DeltaLimit
1 Max Peak	50.0100 MHz	52.26	
2 Max Peak	50.0100 MHz	52.29	
1 Max Peak	51.0000 MHz	52.83	
2 Max Peak	51.0000 MHz	52.81	
1 Max Peak	51.9900 MHz	52.99	
2 Max Peak	51.9900 MHz	52.95	
1 Max Peak	53.0100 MHz	53.24	
2 Max Peak	53.0100 MHz	53.05	
1 Max Peak	54.0000 MHz	53.56	
2 Max Peak	54.0000 MHz	53.35	
1 Max Peak	54.9900 MHz	53.19	
2 Max Peak	54.9900 MHz	53.24	
1 Max Peak	56.0100 MHz	53.14	
2 Max Peak	56.0100 MHz	53.19	
1 Max Peak	57.0000 MHz	53.15	
2 Max Peak	57.0000 MHz	53.19	

Fig. 11: A peak list in which trace 1 is a time domain scan and trace 2 is a stepped scan.

The peak list is exported to a spreadsheet. This computes the differences in levels and displays them graphically.

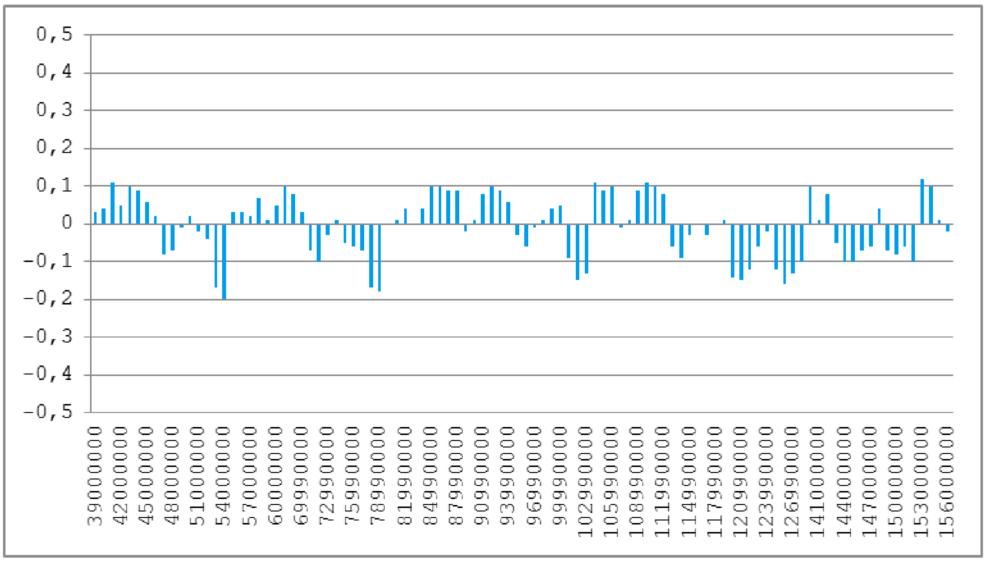
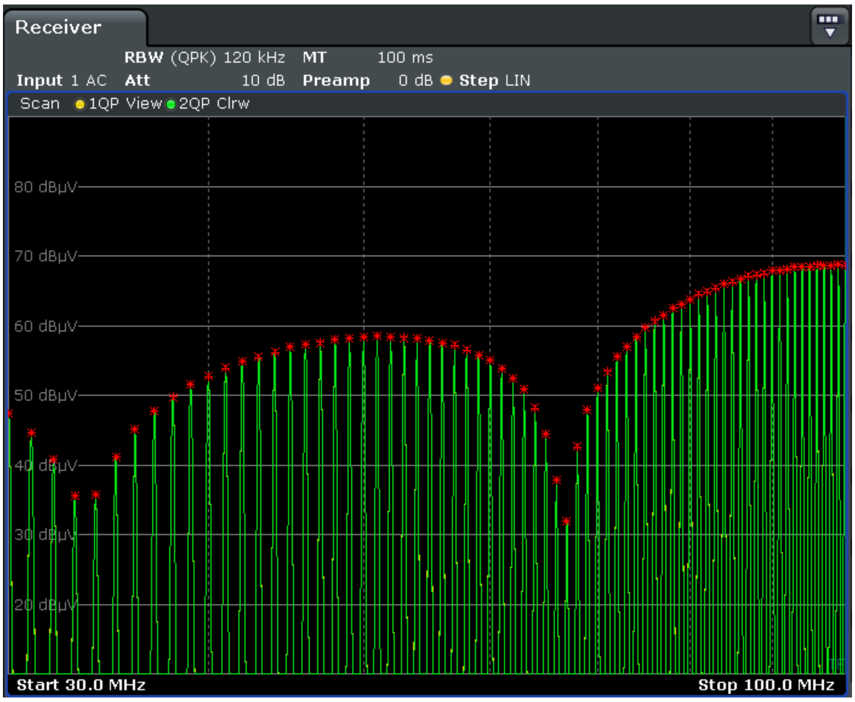


Fig. 12: Graphical display of the differences in level: time domain scan compared to a stepped frequency scan; peak detector, measurement bandwidth of 120 kHz. Y-axis: level difference in dB, x-axis: frequency in Hz.

The small level difference of just a few tenths of a dB shows that the two methods deliver comparable results.

3.1.2 CISPR Band C, Quasi-Peak Detector

The same signal as in the previous section is measured, this time with the quasi-peak detector, in the frequency range from 30 to 100 MHz and with a measurement time of one second.



RBW (QPK) 120 kHz **MT** 100 ms
Input 1 AC **Att** 10 dB **Preamp** 0 dB ● **Step** LIN

Fig. 13: Measured signal spectra, quasi-peak detector, 30 MHz to 100 MHz.

Trace 1 (yellow), measured with a time domain scan, is masked by trace 2 (green), measured with a stepped scan.

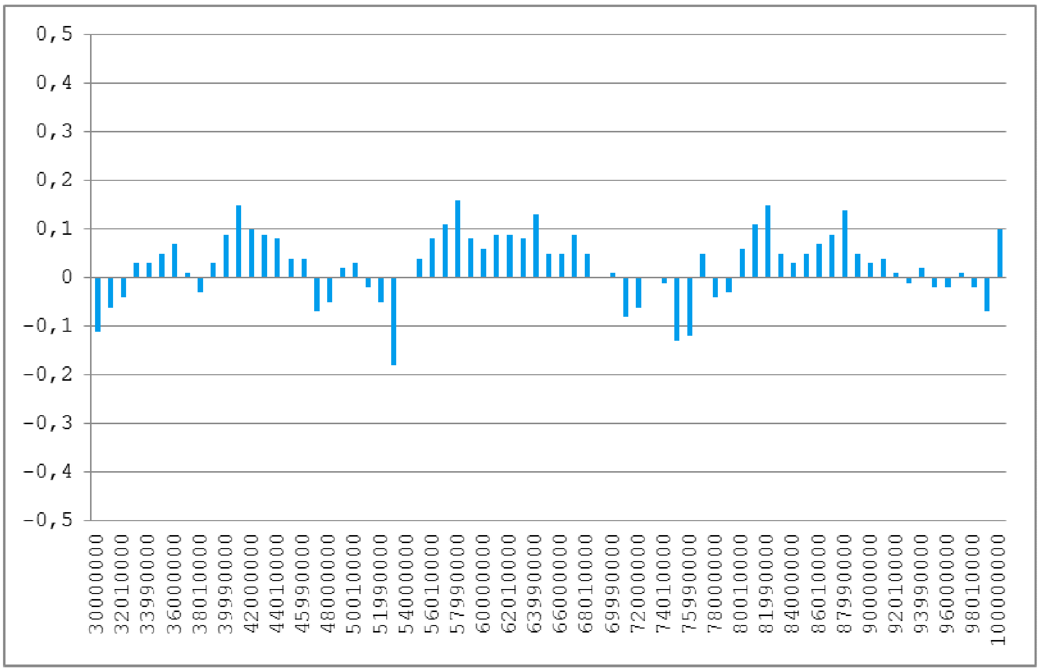
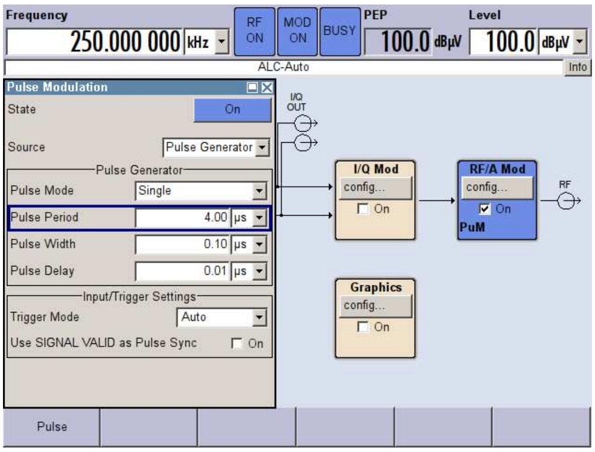


Fig. 14: Graphical display of the differences in level: time domain scan compared to a stepped frequency scan; quasi-peak detector, measurement bandwidth of 120 kHz . Y-axis: level difference in dB, x-axis: frequency in Hz.

3.1.3 CISPR Band B, Quasi-Peak Detector

For the measurement in CISPR band B, from 150 kHz to 30 MHz, an R&S SMBV100A vector signal generator supplies a pulse-modulated carrier at 250 kHz, with a pulse period of 4.00 µs and a pulse width of 0.10 µs.


Frequency 250.000 000 kHz
PEP 100.0 dBµV
Level 100.0 dBµV
ALC-Auto

Pulse Modulation
State On
Source Pulse Generator

Pulse Generator
Pulse Mode Single
Pulse Period 4.00 µs
Pulse Width 0.10 µs
Pulse Delay 0.01 µs

Input/Trigger Settings
Trigger Mode Auto
Use SIGNAL VALID as Pulse Sync ☐ On

Fig. 15: Settings on the SMBV100A signal generator.

Receiver

RBW (QPK) 9 kHz MT 100 ms

Input 1 DC Att 10 dB Preamp 0 dB Step LIN

Scan 1QP View 2QP Clrw

Start 150.0 kHz

Stop 30.0 MHz

Fig. 16: Measured signal spectra, quasi-peak detector, 150 MHz to 30 MHz.

Trace 1 (yellow) was measured with a time domain scan, trace 2 (green) with a stepped scan.

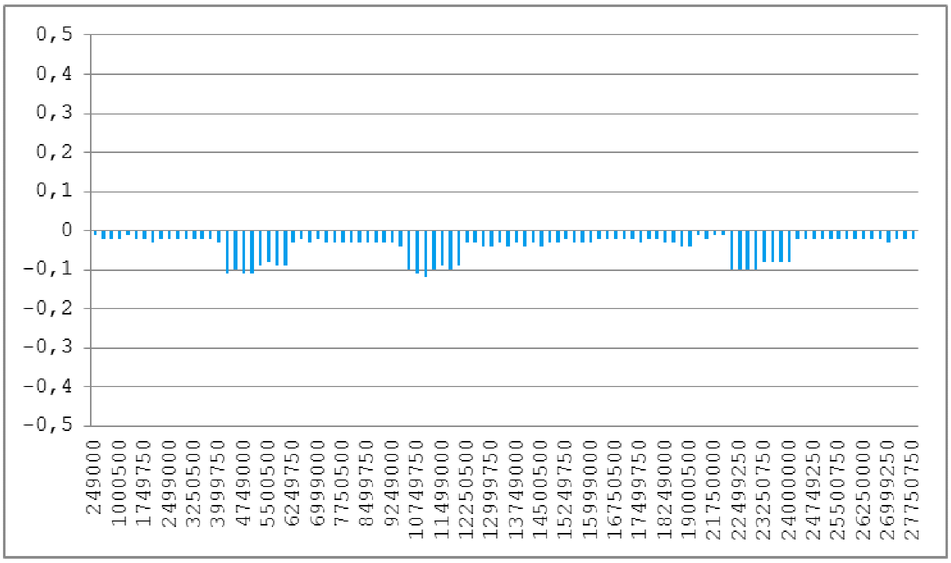


Fig. 17: Graphical display of the differences in level: time domain scan compared to a stepped frequency scan; quasi-peak detector, 9 kHz measurement bandwidth. Y-axis: level difference in dB, x-axis: frequency in Hz.

In all the frequency ranges measured and with various detectors, the time domain scan and the stepped frequency scan deliver practically the same level values. Repeated runs with different instruments yielded similar results.

3.2 Comparison of Measurement Speeds

The comparison of the R&S ESR's measurement times is based on the frequency bands and measurement bandwidths typically used in EMC testing, both under commercial standards and in the automotive sector. CISPR 16-2-1 requires that the measurement time be sufficiently long to detect the highest signal level for changing signals. In this comparison, measurement times of 10 ms and 100 ms were used for the peak detector and one second for the quasi-peak detector. The test receiver automatically adjusts for all settling times and internal processing times so that the measurement time configured and the actual observation time are the same. As table 1 shows, the FFT-based time domain scan reduces overall measurement times by orders of magnitude: The quasi-peak scan in CISPR band B, from 150 kHz to 30 MHz, takes just two seconds as opposed to more than three hours. Even in bands C and D, from 30 MHz to 1 GHz, the spectrum measurement with the quasi-peak detector only takes around 80 seconds, at measurement bandwidths of both 120 kHz and 9 kHz.

Measurement times

Frequency range	Weighting detector, measurement time, measurement bandwidth (no. of test points)	Stepped frequency scan	Time domain scan
CISPR band B 150 kHz to 30 MHz	Pk, 100 ms, 9 kHz (13 267)	1 326 s	117 ms
CISPR band B 150 kHz to 30 MHz	QP, 1 s, 9 kHz (13 267)	3.6 h	2 s *
Band C/D 30 MHz to 1 GHz	Pk, 10 ms, 120 kHz (32 334)	323 s	630 ms
Band C/D 30 MHz to 1 GHz	Pk, 10 ms, 9 kHz (431 000)	4 310 s	850 ms
Band C/D 30 MHz to 1 GHz	QP, 1 s, 120 kHz (32 334)	approx. 9 h	80 s *

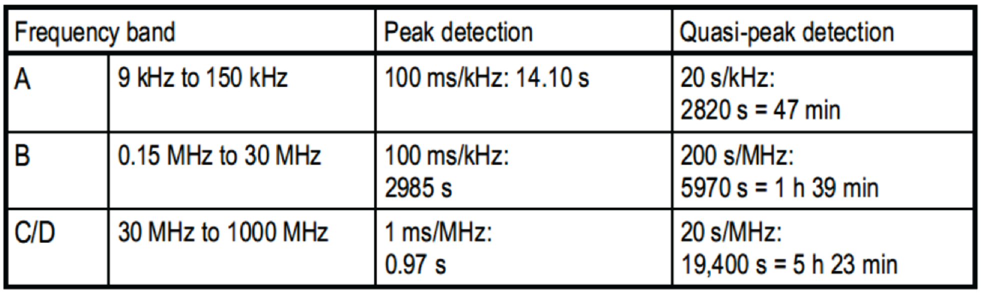
* incl. 1 s settling time per FFT segment in QP analysis

Table 1: Comparison of overall measurement times in a stepped frequency scan and a time domain scan.

4 Choosing the Right Measurement Time

When measuring an unknown disturbance signal in a frequency spectrum, the EMI test receiver must analyze a specific frequency range – ideally, in as short a time as possible. In practice, settling time is relevant in connection with narrow measurement bandwidths. The EMI test receiver takes this into account automatically. However, users must always consider how the disturbance signal behaves versus time. Continuous and clocked narrowband disturbance signals and continuous, intermittent broadband disturbance signals can occur. To correctly measure intermittent disturbance signals, it is essential to configure a sufficiently long measurement time that will allow the highest level to be recorded reliably.

CISPR 16 stipulates the maximum permitted sweep/scan speeds. These were used to calculate the sweep/scan times for the CISPR bands shown in table 1.

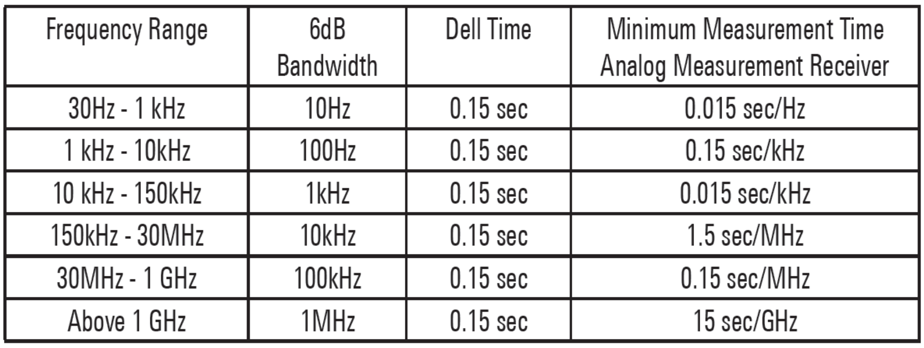


Frequency band		Peak detection	Quasi-peak detection
A	9 kHz to 150 kHz	100 ms/kHz: 14.10 s	20 s/kHz: 2820 s = 47 min
B	0.15 MHz to 30 MHz	100 ms/kHz: 2985 s	200 s/MHz: 5970 s = 1 h 39 min
C/D	30 MHz to 1000 MHz	1 ms/MHz: 0.97 s	20 s/MHz: 19,400 s = 5 h 23 min

Table 2: Minimum sweep/scan times for peak and quasi-peak weighting in line with CISPR 16-2-1.

The times shown in table 2 are minimums that apply to sinusoidal continuous signals. Depending on the type of disturbance signal, the times may need to be increased in order to capture a disturbance signal at its maximum level. This applies even to the quasi-peak detector, which always requires long measurement times. The CISPR standard actually calls for measurement times of up to 15 seconds for discontinuous signals.

MIL-STD-461F, too, defines minimum measurement times for analog test receivers and minimum observation times for synthesizer-based test receivers. The following also applies here: For instruments that only generate disturbances at intervals, the measurement time must be extended so that it is sufficiently long to record every disturbance that occurs.



Frequency Range	6dB Bandwidth	Dell Time	Minimum Measurement Time Analog Measurement Receiver
30Hz - 1 kHz	10Hz	0.15 sec	0.015 sec/Hz
1 kHz - 10kHz	100Hz	0.15 sec	0.15 sec/kHz
10 kHz - 150kHz	1kHz	0.15 sec	0.015 sec/kHz
150kHz - 30MHz	10kHz	0.15 sec	1.5 sec/MHz
30MHz - 1 GHz	100kHz	0.15 sec	0.15 sec/MHz
Above 1 GHz	1MHz	0.15 sec	15 sec/GHz

Table 3: Bandwidths and measurement times taken from MIL-STD-461F.

The example that follows compares the properties of a stepped frequency scan with those of a time domain scan. A signal generator supplies a carrier at 100 MHz that is pulse-modulated with a period of 12 ms. The test receiver conducts measurements with an observation time of 10 ms per frequency step. A classic stepped frequency scan produces the following trace:

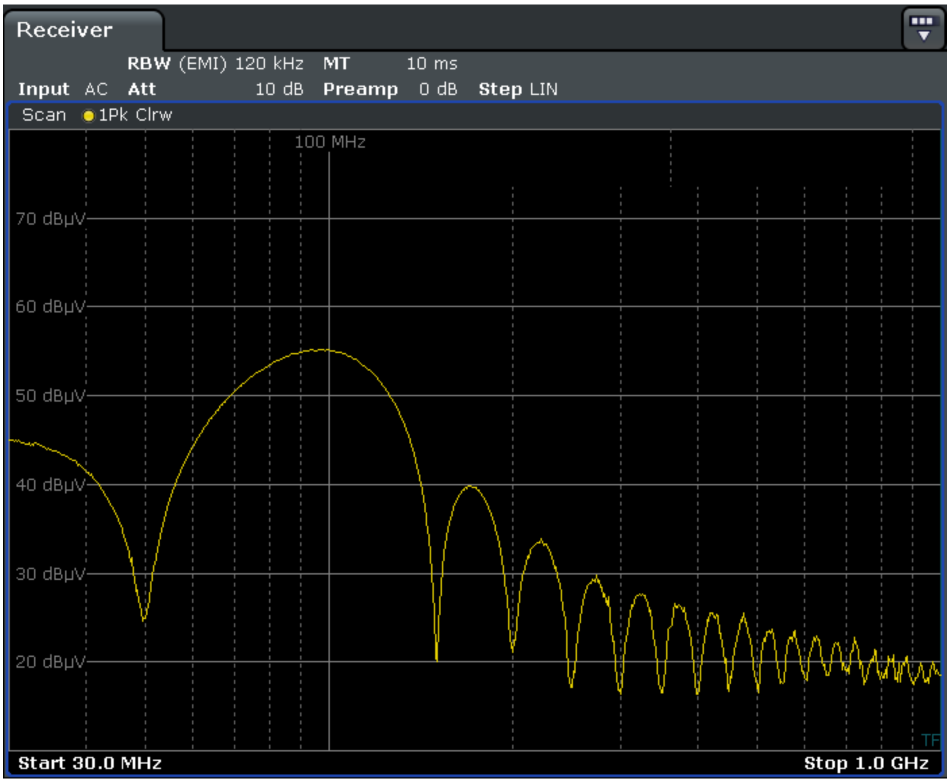


Fig. 18: Stepped scan with a measurement time of 10 ms.

Close examination of the measured values using the zoom function reveals that a pulse was not always captured at every single step. This behavior can be expected with an observation time of 10 ms and a pulse spacing of 12 ms.

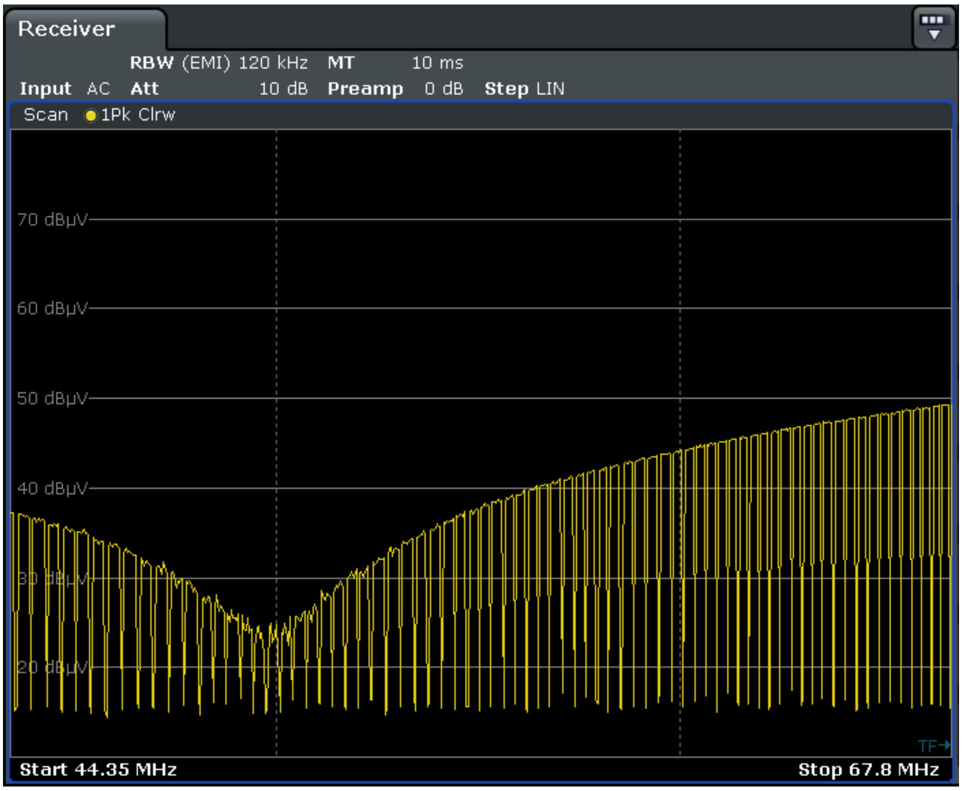
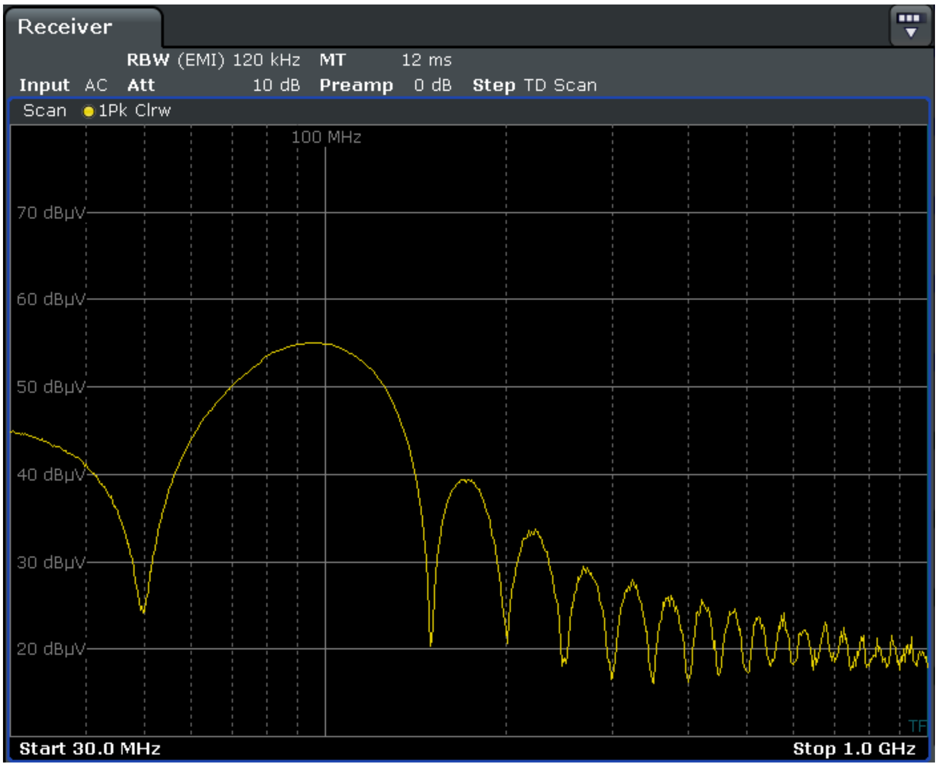


Fig. 19: Stepped scan with a measurement time of 10 ms and the frequency axis stretched.

In Fig. 18, however, the trace is closed. The receiver combines all the measured values that fall on a single display pixel and shows only the highest level value. Here, 691 pixels represent 24 250 measured values. The individual values are only visible if the frequency range is stretched to the point that each pixel represents a single measured value. In Fig. 19 it is possible to see that there is not always a pulse in each measurement interval otherwise the trace would be closed.

The time domain scan observes entire frequency ranges during the measurement time. If the measurement time is at least as long as the signal period, the scan captures the signal completely, without gaps.



Receiver

RBW (EMI) 120 kHz MT 12 ms

Input AC Att 10 dB Preamp 0 dB Step TD Scan

Scan ● 1Pk Clrw

Start 30.0 MHz

Stop 1.0 GHz

Fig. 20: Time domain scan with a measurement time of 12 ms, signal with a pulse period of 12 ms.

If the measurement time drops below the pulse period, there are points at which no pulse occurs during the measurement time. The signal is not visible in parts of the spectrum that correspond to the length of an FFT block, and not just in individual frequency steps as shown in Fig. 19.

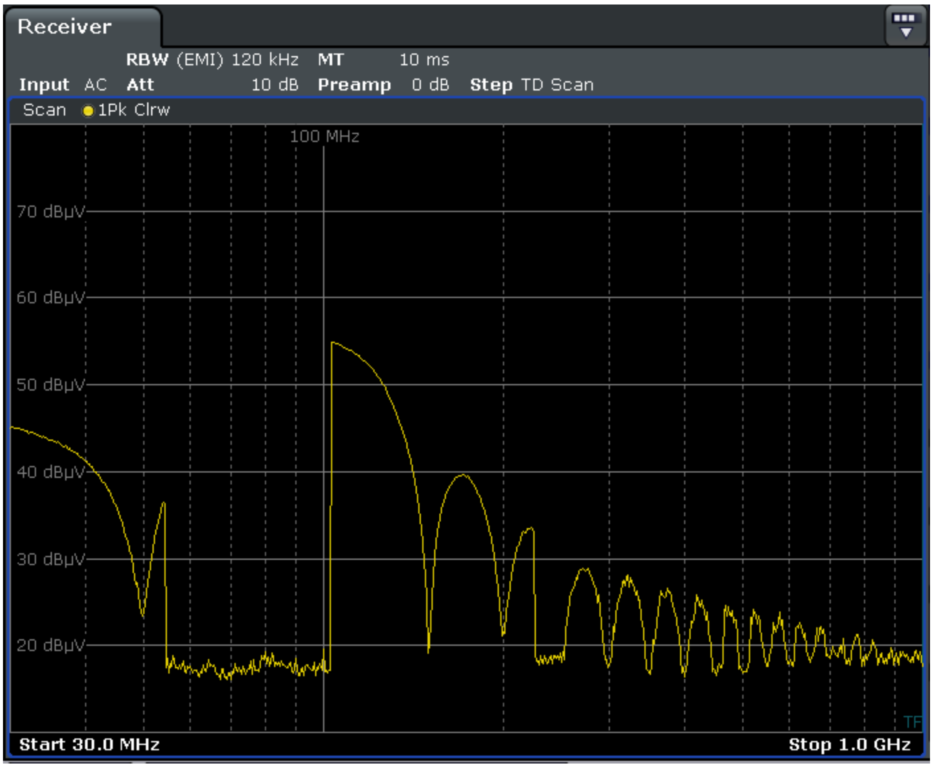
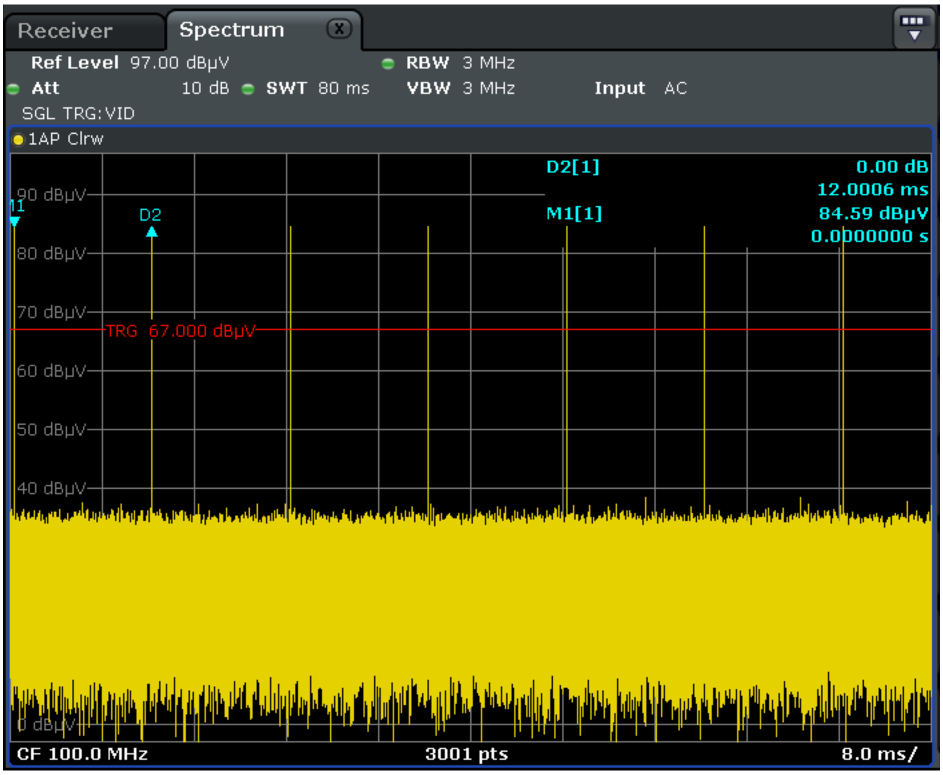


Fig. 21: The measurement time is shorter than the signal's pulse period.

With measurements conducted using a time domain scan, it is especially important to configure the measurement time to suit the signal measured. Gaps in the spectrum are an indication that the measurement time is too short. Given that the overall measurement time is generally much shorter in time domain scans, users can increase the measurement time (i.e. the observation time per FFT area). Even so, the overall measurement time remains short in comparison with a stepped frequency receiver.

If users are not sure how the measured signal behaves versus time, they can use the R&S ESR's spectrum analyzer functionality. In the zero-span view, they can obtain a stable display with the video trigger and measure the period using the marker.



Ref Level 97.00 dBµV
Att 10 dB
SWT 80 ms
RBW 3 MHz
VBW 3 MHz
Input AC
SGL TRG:VID
1AP Clrw

D2[1] 0.00 dB
12.0006 ms
M1[1] 84.59 dBµV
0.0000000 s

TRG 67.000 dBµV

CF 100.0 MHz
3001 pts
8.0 ms/

Fig. 22: Zero-span display of a pulse-modulated carrier.

The measurement time set on the receiver must be at least as long. Better still, there should be a safety margin to accommodate fluctuations in pulse periods.

5 Summary

The R&S ESR EMI test receiver shows that FFT-based time domain scanning significantly reduces test times, both in preview measurements and in final measurements. The measurements are performed in line with the requirements set out in the CISPR 16-1-1 standard. With a time domain scan, measurements are up to 6000 times faster than with a conventional stepped scan. The investigations confirm that the measurement uncertainty is the same with both approaches. To obtain reliable measurement results, it is important to choose the right measurement time. It must be sufficiently long to allow the receiver to reliably capture the highest level of pulsed and changing signals. The CISPR and MIL-STD-461 standards both expressly require this. Thanks to the sizable increase in measurement speed, this is something that can be done easily with the R&S ESR without greatly extending the overall measurement time.

References:

CISPR 16-3 4.10. Background on the definition of the FFT-based receiver.

CISPR 16-2-1. Table 1 - Minimum scan times for the three CISPR bands with peak and quasi-peak detectors

MIL-STD-461F APPENDIX A. Table II. Bandwidth and measurement time

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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