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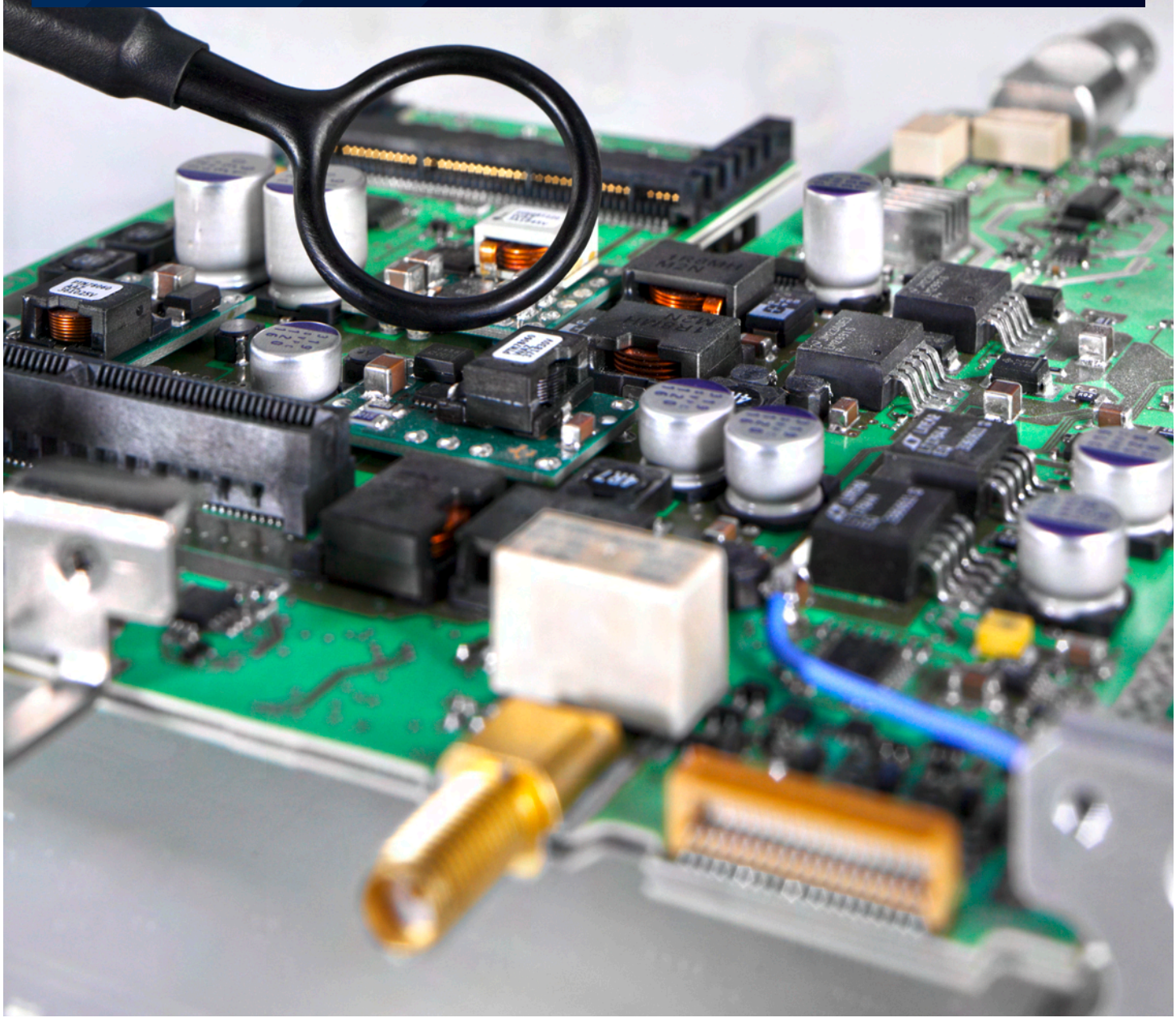
Make ideas real

PRECOMPLIANCE TESTING UP TO 3 GHz

Flyer | Version 01.00



WHAT IS EMC AND WHY IS IT IMPORTANT?

All electronic devices emit electromagnetic waves while they operate. For some it is an intended function, whereas for others it is an undesired byproduct. These emissions can be strong enough to interfere with other electronic devices.
Electromagnetic compatibility (EMC) is mandatory for all electronic products. It is strictly regulated by development and production standards to ensure products' safe operation next to other electronic devices. EMC is important in areas where precise tasks are carried out by mobile phones and computers, automated vehicles and aircraft, and where even slight disturbances might cause serious unforeseen consequences.

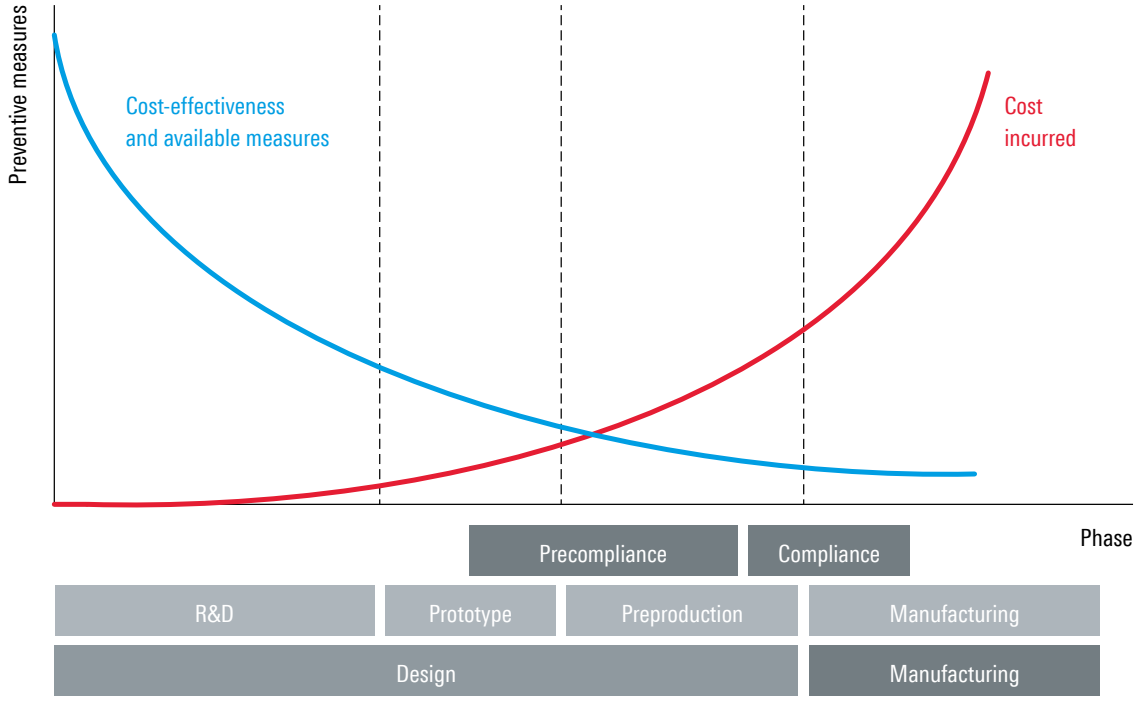
As illustrated in the figure below, precompliance and debugging tests should already be performed during prototyping and preproduction stages of product development to ensure that EMC standards are adhered to. Development budget and time-to-market can be met only if EMC problems are found and addressed early in the development process – in contrast to solving them during final development phases or during production. This reduces the possibility of having to redesign a product to eliminate EMC testing failures, saves time and ensures that the product is ready for launch.

EMC testing is a critical part of any product development journey, since electromagnetic interference can come from many sources, with different characteristics and mechanisms. Electromagnetic interference (EMI) is always an unwanted occurrence, and the overall aim is to eliminate or reduce it below certain limits.

EMI can be continuous, existing constantly in the background, or it can occur for a short period of time. Radiated and conducted emissions refer to the way EMI is propagating from the source to the device affected by the noise.

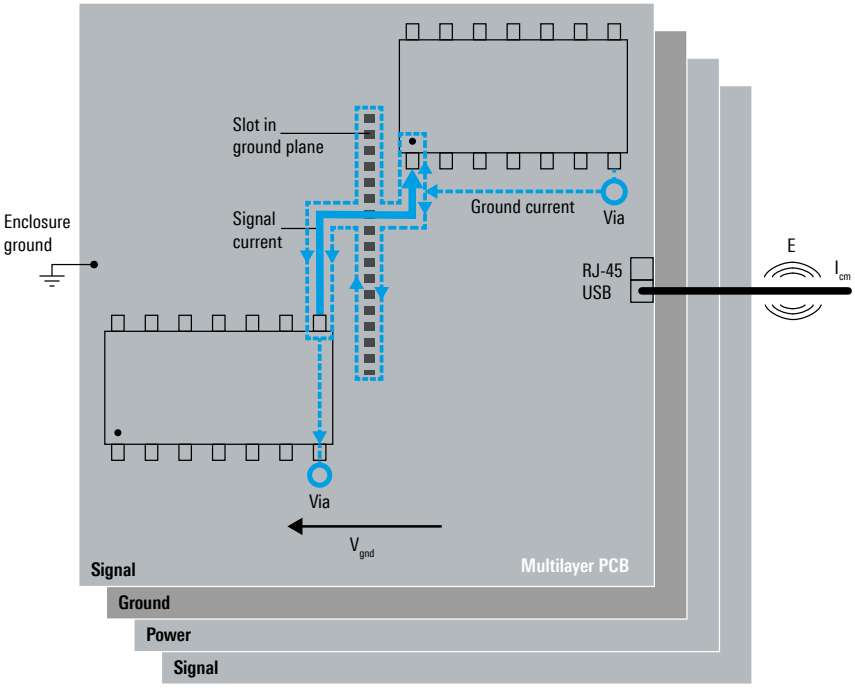
Radiated emissions are electromagnetic waves emitted by a device; they propagate over the air, and can affect other devices.

Conducted emissions are electromagnetic waves that propagate through electronic connections (e.g. cables) from one device to other directly connected devices.



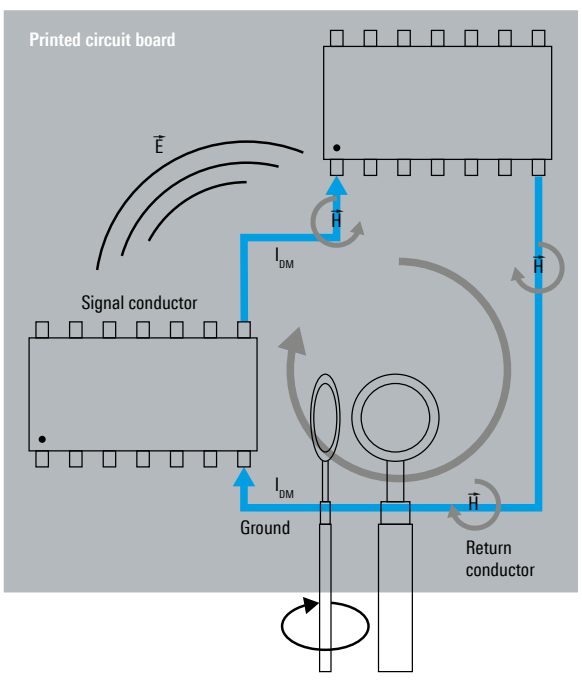
Unwanted EMI noise can be classified into two types: differential-mode and common-mode RF emissions.

Differential-mode RF emissions



Differential-mode RF emissions from printed circuit boards occur due to the flow of current via signal paths in which the forward and return conductors are not routed together, thereby forming a conductor loop. The interference source is a result of the circuit's primary function, i.e. transferring data between two components of the circuit. Near-field test equipment can be used to detect sources of differential-mode RF emissions. Here, we use loop antennas with appropriate directivity, and the loop antenna must be rotated during the measurement in order to find the maximum value of the RF emissions.

Common-mode RF emissions



Common-mode RF emissions occur due to undesired parasitic effects. This problem is common with multilayer printed circuit boards in cases where slots or other discontinuities in the ground plane prevent the return current for transmitted signals from flowing close to the signal line. In the picture, the source is a slot in the ground plane that causes a parasitic inductance in the return conductor. This causes a voltage drop between different points in the ground plane. If we connect a cable to a printed circuit board of this type, it will function like an antenna and allow a common-mode current to flow – an undesired effect. In practice, common-mode currents are one of the main causes of undesired RF emissions. Near-field test equipment can be used to detect sources of common-mode RF emissions. Magnetic near-field probes that are capable of detecting common-mode current (or the resulting field) are suitable for this task.

Rohde & Schwarz has extensive experience in EMI precompliance testing and provides solutions for EMI debugging, precompliance and compliance testing. They help test circuit layouts at early stages, and to localize and eliminate possible sources of emissions.

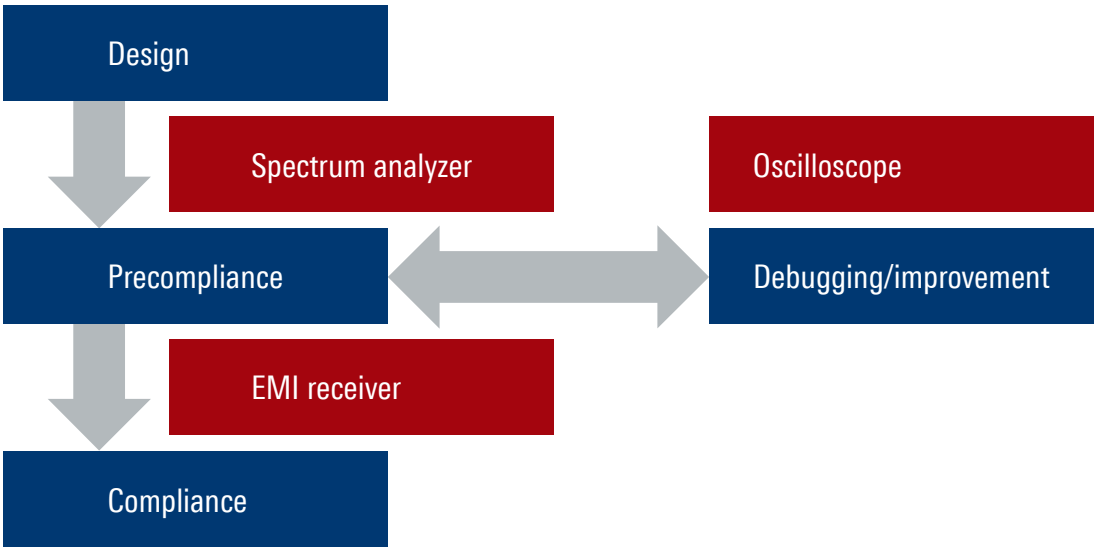
BASIC EMI DEBUGGING PROCESS FOR RADIATED AND CONDUCTED EMISSIONS

Although the product development process can have its peculiarities, it is in most cases illustrated as a sequence of standard steps. Each step requires continuous testing that can be performed by different types of test equipment. Precompliance and debugging tests, for example, are most commonly done with the help of a spectrum analyzer or an oscilloscope, while compliance tests usually rely on EMI receivers.

Near-field measurements are used to localize the source of interference.

After the noise source has been located, the behavior of the interference can be analyzed and corrective measures assessed.

A final precompliance measurement is performed before going into the compliance stage.



OSCILLOSCOPE VERSUS SPECTRUM ANALYZER FOR EMI DEBUGGING AND PRECOMPLIANCE TESTS

EMI debugging revolves around a simple idea – to have a convenient and affordable setup that can be used during product design for verification and early detection of potential problems.

To perform EMI tests, depending on existing lab equipment and needs, you can use a spectrum analyzer or an oscilloscope and a near-field probe set. EMI test receivers are also an option. They offer high dynamic range and meet the most stringent requirements. However, they are best suited for the last stages of EMC precompliance and compliance testing.

Near-field probes are used as diagnostic tools for locating EMC problems, e.g. on circuit boards, integrated circuits, cables and shielding – ideal for emission measurements from 30 MHz to 3 GHz.

Each probe has different pros and cons, so it is beneficial to have a set of probes at your disposal. Probing always starts with bigger probes to locate the general problematic area more easily, and then uses smaller ones to locate the exact source of the noise.

Fast changes of current (high di/dt) and fast changes of voltage (high dv/dt) cause emissions.

Areas of high di/dt can be localized by means of an H-field probe, typically a probe with loop shape.

E-field probes help to detect areas of high dv/dt. Once the area with high di/dt or high dv/dt has been found, a smaller probe size is used to identify the point of emission with higher resolution.

If you are looking to perform EMI precompliance tests up to 3 GHz, Rohde & Schwarz offers a portfolio of instruments dedicated to cost-efficient EMI testing and debugging. Some of the Rohde & Schwarz instruments with the best price/functionality ratio are:

- **Oscilloscopes:** R&S®RTM3000, R&S®RTA4000, R&S®RTE1000
- **Spectrum analyzers:** R&S®FPL, R&S®FPC, R&S®FPH
- **EMI test receivers:** R&S®ESL
- **Probes:** R&S®HZ-15 (with five probes) is used for both electric and magnetic near-field examination, R&S®HZ-17 (with two probes) focuses on the magnetic field

All of these instruments tackle EMI problems from different perspectives. Each instrument category offers a different approach and diagnostic techniques that can complement each other at different stages of the product development cycle.

EMI DEBUGGING WITH AN OSCILLOSCOPE

Benefits
► Visible correlation between frequency and time domain
► Wide and instantaneous frequency coverage
► Deep memory for capturing long signal sequences
► Gated FFT analysis for correlated time-frequency analysis
► Frequency masks for triggering on intermittent events with lab-class instruments
► Overlapping FFT computation with color grading with lab-class instruments

Limitations
► Dynamic range is limited
► No preselection available
► No standard-compliant detectors (i.e. CISPR)

Oscilloscopes are typically already available at the R&D engineer's bench. Their ability to perform EMI debugging tasks provides a more cost-effective solution that eliminates the need for additional equipment. State-of-the-art oscilloscopes are ideal tools for EMI debugging because they are able to transform signals from the time domain into the frequency domain (by fast Fourier transform (FFT)). They can easily detect electromagnetic interference from electronic circuits with high speed and accuracy. The basic working principle of an oscilloscope is to capture signals when the input signal exceeds a specific trigger value, which helps to capture the peaks of the noise signal.

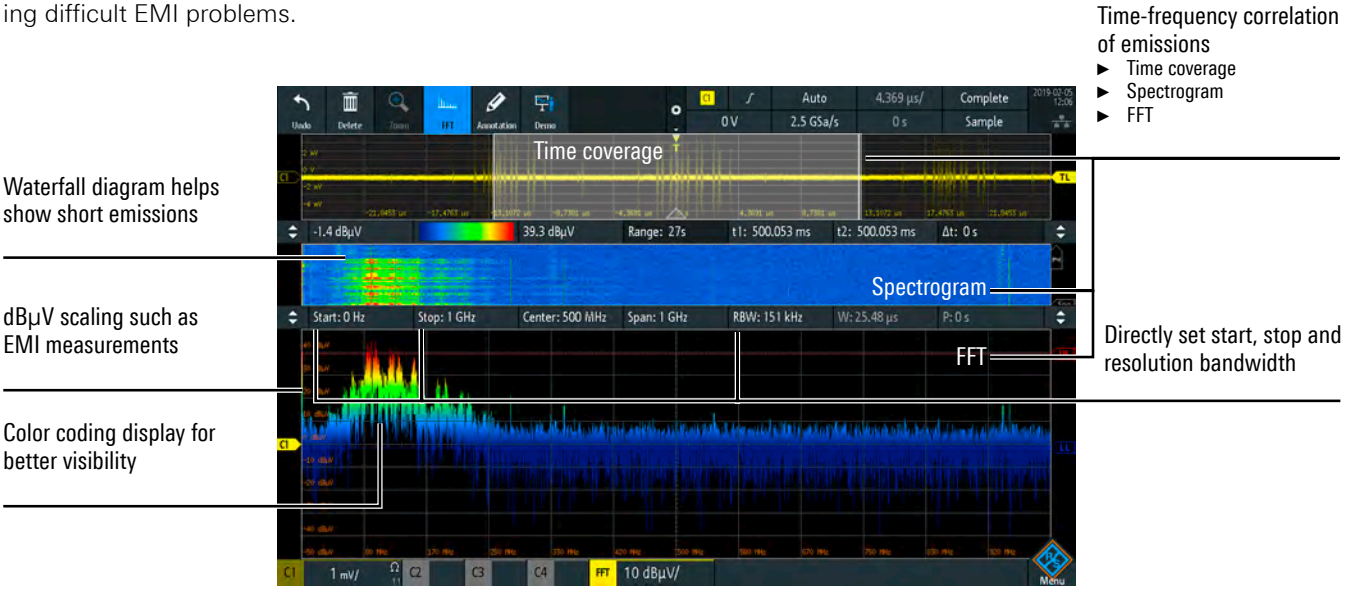
The key requirements for an oscilloscope to be useful for EMI applications:

- Low-noise frontend in order to have enough dynamic range when measuring weak emissions
- Direct input of frequency parameters such as start and stop frequency or resolution bandwidth
- Fast and efficient FFT analysis, which is particularly important for near-field probing since immediate feedback about the noise level at a specific location is important

For debugging and locating emission sources using an oscilloscope, a combination of the R&S®RTM3000 or the R&S®RTA4000 oscilloscope and the R&S®HZ-17 near-field probe set can do an excellent job.

Advanced oscilloscope FFP capabilities: correlation of time and frequency information

Medium-class oscilloscopes such as the R&S®RTM3000 and R&S®RTA4000 fulfill these requirements and prove to be very useful for EMI debugging issues as well as early precompliance measurements in the R&D lab. In addition to that, lab-class oscilloscopes have extended trigger and analysis capabilities that provide valuable tools for analyzing difficult EMI problems.

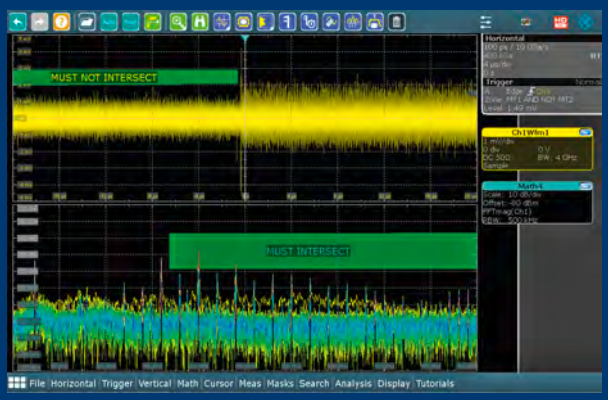


Comparison of lab-class versus medium-class oscilloscopes for EMI debugging

Feature	Lab-class oscilloscopes R&S®RTE1000, R&S®RTO2000	Medium-class oscilloscopes R&S®RTB2000, R&S®RTM3000, R&S®RTA4000
(Widely) independent choice of time scale and frequency settings	•	–
Overlap FFT functionality	•	–
Frequency masks	•	–
Time gated FFT	•	–
Log frequency scale	•	–
dBµV scale	•	•
Direct frequency setting	•	•
Time-frequency correlation	•	•
Waterfall diagram	•	•

Lab-class oscilloscopes' ability to define multiple and different types of triggers for time, frequency and digital signals can be useful in examining the cause and effect of the captured signals.

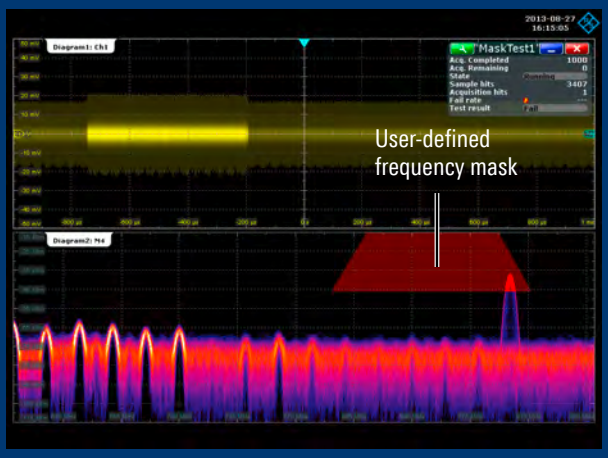
Zone trigger



The zone trigger is activated when a signal either intersects or does not intersect the zone – which can be defined by the user. This allows users to solely concentrate analysis on signals that exceed specific emission limits.

- Available on the R&S®RTO2000, R&S®RTE1000

Mask violation



Similar to the zone trigger, albeit with a slight tweak, the main objective here is to stop the acquisition upon violation of the mask – it works similarly to the time domain trigger mode in oscilloscopes.

- Available on the R&S®RTE1000

Interference behavior

One useful feature of EMI testing with an oscilloscope is correlating time-frequency analysis to reveal how the signal spectrum evolves over time. This method is used where multiple broadband sources exist, e.g. switched power supplies with DC voltage level convertors. The following oscilloscope analysis tools are beneficial for using EMI testing:

- **FFT gating emissions:** By applying FFT gating, you can see how the spectra evolve over time. This is useful for switching events in switched power supplies. FFT gating also isolates spurious spectral components in the time domain.
- **Correlated interference sources analysis:** Embedded RF designs require complex test setups in order to examine their behavior, which is why an oscilloscope with time-correlated measurements across multiple domains is an invaluable tool.
- **History function for the emission analysis:** All previously captured signals are stored in the memory and can be accessed as required. With a timestamp, it is easier to find correlation. All saved signals can be further analyzed with options such as zoom, measurement, math and spectrum analysis. Newly acquired signals can be quickly compared with the ones previously stored in the memory.

When using an oscilloscope to test conducted emissions, the R&S®RTM3000 plus a line impedance stabilization network (LISN) are an ideal combination for debugging.

To measure conducted emissions of a power supply, you need an LISN, for example the R&S®HM6050-2, to decouple the device under test (DUT) from the external power supply.

Once the FFT is applied to the signal, and by selecting the center frequency and span, an oscilloscope can show the time domain and the frequency domain traces – comparable to what you can find on a spectrum analyzer. When comparing emission limits, you need to take into account that the signal might be attenuated due to the LISN.

The EMI filter of the switched mode power supply is responsible for the reduced EMI spectrum; the noise generated at the input of the DC/DC converter is clearly visible in the left screenshot. With the low-pass-filter, you see that the conducted emissions on the input are effectively attenuated. For some frequencies, up to 30 dB attenuation is visible.

EMI spectrum without input filter

EMI spectrum with input filter

EMI DEBUGGING WITH A SPECTRUM ANALYZER

Benefits

- Can easily measure very low amplitudes and high frequencies
- Offers longer gapless recording
- Offers EMI-specific detectors (quasi-peak, CISPR-average)
- Wide dynamic range
- Dual-logarithmic axes display available

Spectrum analyzers are commonly used in precompliance test setups. With built-in CISPR detectors, they offer advanced functions that can simplify EMI debugging. The R&S®FPC1500 spectrum analyzer is an affordable, multipurpose instrument. Providing features of a spectrum analyzer, a signal generator and a network analyzer, it is perfect for EMI precompliance measurements as well as general development, debugging and verification of electronic designs.

For debugging and locating emission sources using a spectrum analyzer, the R&S®FPC1000 and R&S®FPC1500 spectrum analyzers offer outstanding performance. Together with the R&S®HZ-17 near-field probe set, this is an excellent solution used for locating the source and EMI debugging. The R&S®HZ-16 preamplifier improves measurement sensitivity up to 3 GHz, with approx. 20 dB gain and a noise figure of 4.5 dB.

Limitations

- Higher cost of the instrument
- Not as versatile as an oscilloscope

Radiated emissions are inherent to any electrical circuit. By testing radiated emissions, you measure the electromagnetic field strength of unintentional emissions generated by your products.

Setup

- Connect a suitable near-field probe from the R&S®HZ-15 or R&S®HZ-17 probe set to the R&S®FPC1000 or R&S®FPC1500 analyzer RF input
- Move the probe over the board or module under test
- Use R&S®ELEKTRA EMI software (R&S®ELEMI-E) to document the findings

Other available spectrum analyzers for locating the source of unwanted emissions are the R&S®FPL (high-end functions in a lightweight and compact format) and the R&S®FPH (handheld, portable instrument, perfect for situations where mobility is required).

To test **conducted emissions**, you can use the R&S®FPC1000 and the R&S®FPC1500 spectrum analyzers to analyze the level of RF energy coupled to the mains supply. This requires that the RF signal be separated from the mains supply and stabilized to 50 Ω, which is achieved with the R&S®HM6050-2 line impedance stabilization network (LISN).

External software controls and documents the test workflow, i.e. it takes care of LISN line switching. Reporting templates can be used for easy documentation of test results.

The lab is inevitably a noisy and constantly changing electrical environment. A reference ground plane is required for repeatable measurements. Using a shielded chamber is helpful to avoid reception of ambient signals.

Setup

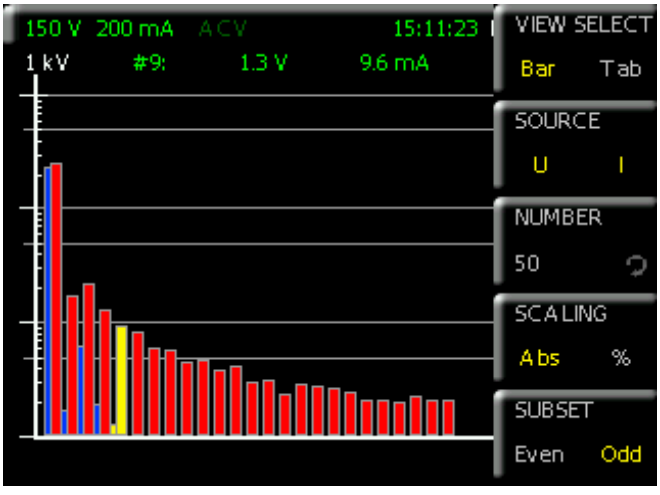
Connect the R&S®HM6050-2 LISN to the:

- Mains supply via an isolated transformer
- DUT
- R&S®FPC1000 or R&S®FPC1500 spectrum analyzer via BNC cable
- PC running R&S®ELEKTRA EMI software (R&S®ELEMI-E) using a serial/USB adapter cable for line switching and a LAN connection to the R&S®FPC for remote control

HARMONICS TESTING

One of the CE marking mandatory standards for power quality includes testing for harmonics to 16 A. Unwanted harmonics increase the heat generated in the electrical system, leading to power losses, greater electricity costs as well as reduced performance of the system itself. Limiting the harmonics is an important task.

In order to obtain CE certification, the harmonic currents must be analyzed to make sure they are within power quality limits, described in IEC/EN 61000-3-2. This standard implies testing for the harmonic currents of all single-phase devices connected to a public low-voltage system. The devices' maximum rated input current should be less than or equal to 16 A. This standard is therefore a part of the EMC/CE examination.



The R&S®HMC8015 power analyzer provides seamless acquisition and real-time signal processing to speed up conducted emissions measurements. For class A equipment, harmonics up to the 40th order must be checked. The R&S®HMC8015 can check harmonics up to the 50th order.

Once the DUT is correctly connected to the instrument, the wizard will guide the user through the measurement and configure the needed parameters. This reduces errors and provides quick and easy measurements. By selecting the region, users can set voltage and frequency adjustments as well as the device class, crest factor, range, and the expected pattern of power consumption. This last point is optional, since the incorrect setting is automatically detected and corrected by the power analyzer.

During the measurement, the user can monitor the current harmonics. When the test is finished, results can easily be exported into an easy-to-use, configurable report.

SUMMARY

EMC precompliance tests help ensure that the product is ready for market launch on time and expensive failures are avoided. EMI testing requires a different approach than routine time domain and other RF measurements. Unwanted EMI noise can come from one or more components of your device, so choosing the best possible tools to perform EMI precompliance and debugging tests increases testing efficiency.

Oscilloscopes together with spectrum analyzers offer a wide range of diagnostic techniques that can be helpful during any stage of the product developmental cycle – ensuring that the product successfully passes full EMC compliance testing, making it ready for market on time, without investing in additional equipment.

EMI debugging with an oscilloscope

- An oscilloscope can be an economically sensible tool to use since it is already available at the engineer's bench
- EMI debugging with an oscilloscope enables correlation of interfering signals with time domain events
- The combination of synchronized time domain and frequency domain analysis with advanced triggers allows quick insight into EMI problems

EMI debugging with an spectrum analyzer

- Spectrum analyzers provide wide dynamic ranges for detecting small signals in the vicinity of large signals
- CISPR detectors and EMI-specific measurements and documentation PC software are available
- Dual-logarithmic axes display is available

Whether you are planning to perform EMI debugging tests with an oscilloscope or a spectrum analyzer, Rohde & Schwarz offers complete solutions in the range up to 3 GHz. For higher-frequency EMI solutions, please feel free to explore the full Rohde & Schwarz portfolio.

Product	Order number	Starting at
EMI debugging and precompliance testing with an oscilloscope		
R&S®RTM3002 oscilloscope	1335.8794.02	
R&S®RTM3004 oscilloscope	1335.8794.04	
R&S®RTA4004 oscilloscope	1335.7700.04	
R&S®RTE1002 oscilloscope	1326.2000.22	
R&S®RTE1004 oscilloscope	1326.2000.32	
R&S®HZ-15 E and H near-field probe set	1147.2736.02	
R&S®HZ-17 H near-field probe set	1339.4141.02	
EMI debugging and precompliance testing with a spectrum analyzer		
R&S®FPC1000 spectrum analyzer	1328.6660K02	
R&S®FPC1500 spectrum analyzer with tracking generator	1328.6660K03	
R&S®FPH handheld spectrum analyzer		
R&S®HZ-15 E and H near-field probe set	1147.2736.02	
R&S®HZ-17 H near-field probe set	1339.4141.02	
R&S®HM6050-2 line impedance stabilization network	3593.0351K02	
R&S®FPC-Z1 cable set for connection from R&S®FPC to R&S®HM6050-2	1328.7444.02	
R&S®ELEMI-E EMI test software	5601.0030.02	
R&S®ELEKTRA license	5601.0018K02	

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Precompliance testing up to 3 GHz
Data without tolerance limits is not binding | Subject to change

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