Keysight Technologies

Essential Capabilities of EMI Receivers

Application Note

KEYSIGHT TECHNOLOGIES

Contents

Introduction

Receivers used for EMC compliance testing require certain features and specifications in order to comply with the appropriate standard. For example, a receiver used for commercial compliance testing must comply with CISPR16-1-1, while a receiver used for military compliance testing must comply with MIL-STD-461. Other features, while optional, can be critical for making measurements or providing analytical capabilities essential for diagnostics. These analytical tools can be valuable in the isolation and identification of emissions problems.

This application note will discuss what makes an EMI receiver fully compliant and provide an overview of some of the most useful internal diagnostic tools for quickly and efficiently analyzing and measuring unwanted emissions. Important features not required by CISPR 16-1-1 or MIL-STD-461 but that are critical for making measurements will also be discussed.

CISPR 16–1–1 Compliance

CISPR is the "Special International Committee on Radio Interference". The committee provides recommendations used by governmental regulatory agencies to establish regulations pertaining to emissions and immunity standards. CISPR 16-1-1 is the standards document that describes the requirements for commercially compliant EMI receivers.

To better understand what is specified in CISPR 16-1-1, we will begin by defining the four CISPR reference bandwidths (200 Hz, 9 kHz, 120 kHz and 1 MHz). The first 3 bandwidths (6 dB) fit a mask specified by CISPR, while the 1 MHz bandwidth is defined by its impulse bandwidth, also specified by CISPR. There are five CISPR bands: A, B, C, D, and E, which fall within the range of 9 kHz to 18 GHz. Each CISPR band is paired with one of the four CISPR reference bandwidths.

Table 1. CISPR bands and the corresponding reference bandwidths CISPR Band

Bands	Frequency range	CISPR reference bandwidth
A	9 to 150 kHz	200 Hz
B	150 kHz to 30 MHz	9 kHz
C	30 to 300 MHz	120 kHz
D	300 MHz to 1 GHz	120 kHz
E	1 to 18 GHz	1 MHz

Also specified in CISPR 16-1-1 are four detectors: Peak, Quasi-peak, EMI average and RMS average. There can be other detectors available as part of the receiver, such as average and negative peak, but they are not specified by CISPR. If the receiver offers a spectrum analyzer mode, then even more detectors are made available to the user.

CISPR 16-1-1 Compliance (continued)

Of all the detectors, the peak detector enables the fastest possible sweep time. The peak detector displays the max value of each trace bucket (also known as a frequency bin) and does not use any type of averaging. This provides good results for CW signals but does not give a good representation of random noise.

The CISPR-recommended method of measurement suggests measuring with the peak detector first. If the DUT passes the limit, then the test is done. If the DUT does not pass, then the user must re-measure using the quasi-peak or EMI average detector.

In addition to the detectors and bandwidths, the receiver must also meet these requirements:

- Specified amplitude accuracy
  - ± 2 dB, 9 kHz to 1 GHz
  - ± 2.5 dB, > 1 GHz to 18 GHz
- Input impedance of 50 ohms; deviations specified as VSWR
- Ability to pass product immunity in a 3 V/m field
- Ability to pass the CISPR pulse test
- Other specific harmonic and intermodulation requirements

MIL-STD-461 Compliance

While receiver compliance to CISPR 16-1-1 is needed for commercial compliance, for military testing MIL-STD-461 is the U.S. military standard on EMC. It was created by the Department of Defense (DoD) and describes how to test equipment for emissions and susceptibility. MIL-STD-461 Section 4.3.10 defines the requirements of the EMI receiver. The first requirement is that it must have the necessary resolution bandwidths (RBW). The RBW needed depends on the frequency range, as shown in Table 2.

Table 2. MIL bands and corresponding resolution bandwidths

Frequency range	MIL-STD-461 resolution bandwidth (6 dB BW)
30 Hz to 1 kHz	10 Hz
1 kHz to 10 kHz	100 Hz
10 kHz to 150 kHz	1 kHz
150 kHz to 30 MHz	10 kHz
30 MHz to 1 GHz	100 kHz
Above 1 GHz	1 MHz

Second, the receiver must have sufficient sensitivity. The displayed average noise level (DANL) of the instrument must be lower than the limit in order to accurately measure low level emissions. A good rule of thumb is to have to have at least 10 dB of margin. Third, the receiver must have a peak detector. Unlike other standards, MIL-STD-461 accepts only measurement data with the peak detector. Measurements with other detectors are not allowed.

In addition to the resolution bandwidths, sensitivity, and peak detector, the receiver must also meet these requirements:

- Dwell times (specified in MIL-STD-461)
- ± 2 dB amplitude accuracy
- ± 2% frequency accuracy

Important features not required by CISPR 16-1-1 or MIL-STD-461

Additional EMI receiver features that make measuring easier and more efficient, but are not requirements by CISPR 16-1-1 or MIL-STD-461, include limit lines, limit pass/fail indication, correction factors (for transducers), signal lists with sorting capability, time domain scanning, and more.

Limit lines

First, let's consider limit lines. When selecting an EMI receiver, a user will want to consider the following:

– Are the limits the user needs to test available with the receiver?

– Can new limits be added to the receiver? Can existing limits be edited?

– Is it easy to identify a signal that fails the limit?

– Can more than one limit be displayed at a time?

The Keysight Technologies, Inc. MXE EMI receiver provides all of these capabilities and includes a built-in library of commonly used limit lines.

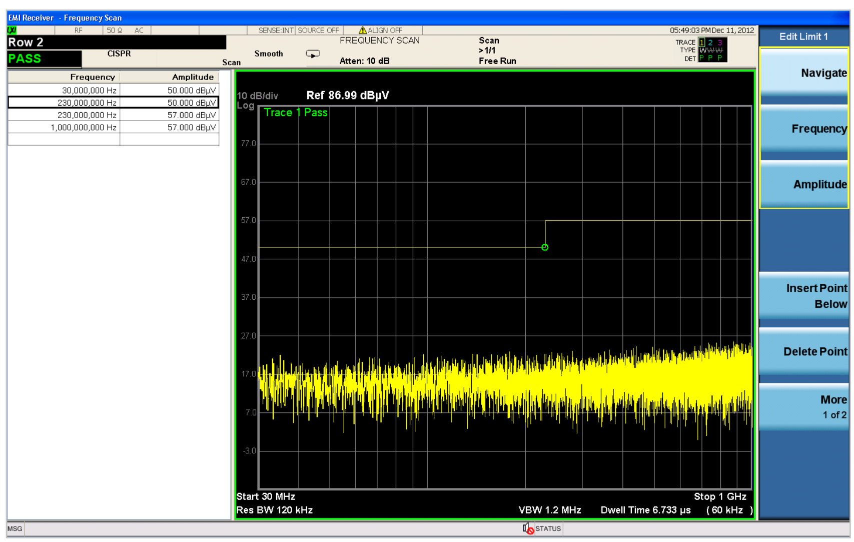


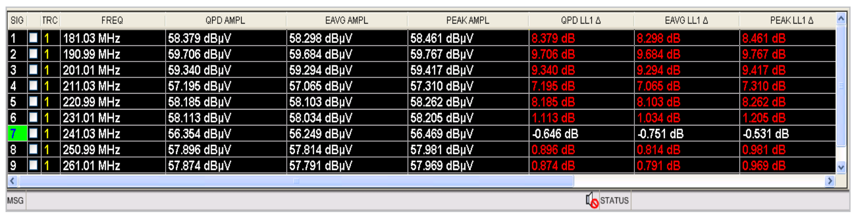
Figure 1. MXE EMI receiver limit line editor.

Correction factors

Correction factors are crucial in making accurate measurements. Transducers such as antennas, LISNs (Line Impedance Stabilization Networks), current probes, current clamps, cables and amplifiers have unique frequency-dependent correction factors that are usually supplied by the manufacturer or calibration facility. These correction factors are added to or subtracted from the received amplitude values to compensate for the transducer gain or loss and allow the receiver to display the actual emission field strength amplitude at the transducer. Some receivers, such as the MXE, have a built-in library of transducer factors that can be easily recalled for commonly used transducers. Many times the user must define their own transducer factor. That is why the MXE has an editor to edit existing transducer factors or create new ones.

Signal lists

Why is a signal list important? The signal list is where scan results and individual signal measurements are stored. In the MXE, 2000 signals can be stored in a list for use by technicians and engineers to identify failed signals and to analyze the data for debugging.



SIG		TRC	FREQ	QPD AMPL	EAVG AMPL	PEAK AMPL	QPD LL1 Δ	EAVG LL1 Δ	PEAK LL1 Δ
1		1	181.03 MHz	58.379 dBµV	58.298 dBµV	58.461 dBµV	8.379 dB	8.298 dB	8.461 dB
2		1	190.99 MHz	59.706 dBµV	59.684 dBµV	59.767 dBµV	9.706 dB	9.684 dB	9.767 dB
3		1	201.01 MHz	59.340 dBµV	59.294 dBµV	59.417 dBµV	9.340 dB	9.294 dB	9.417 dB
4		1	211.03 MHz	57.195 dBµV	57.065 dBµV	57.310 dBµV	7.195 dB	7.065 dB	7.310 dB
5		1	220.99 MHz	58.185 dBµV	58.103 dBµV	58.262 dBµV	8.185 dB	8.103 dB	8.262 dB
6		1	231.01 MHz	58.113 dBµV	58.034 dBµV	58.205 dBµV	1.113 dB	1.034 dB	1.205 dB
7		1	241.03 MHz	56.354 dBµV	56.249 dBµV	56.469 dBµV	-0.646 dB	-0.751 dB	-0.531 dB
8		1	250.99 MHz	57.896 dBµV	57.814 dBµV	57.981 dBµV	0.896 dB	0.814 dB	0.981 dB
9		1	261.01 MHz	57.874 dBµV	57.791 dBµV	57.969 dBµV	0.874 dB	0.791 dB	0.969 dB

MSG STATUS

Figure 2. MXE EMI receiver signal list.

Tools to aid signal maximization

Prior to making final measurements, it is critical that the final measurement frequencies be adjusted to capture the maximum signal amplitude. Suspect frequencies and amplitudes captured during prescan may not always capture the maximum emission level due to:

- Time-varying emissions: An example of this is a frequency-modulated emission.
- The number of measurements per resolution bandwidth selected by the user: EMC measurements are typically made with between 2 and 4 data points per specified resolution bandwidth. It is possible that the emission frequency would not be aligned with the specific measurement point.

Tools to aid signal maximization (continued)

Having the ability to adjust the suspect frequency to the peak of the emission prior to final measurement ensures that the user can measure the maximum amplitude. There are three receiver functions which allow this frequency adjustment:

– Meters center frequency adjustment: This basic capability is used to peak the center frequency for stable signals, but it can't be used to peak for modulated signals and the spectrum of the signal is not visible.

– Linked meters and spectrum analysis view: By linking the meters frequency to the spectrum analyzer center frequency, users can easily switch between signal views. In the spectrum analyzer view, users have the full power of a spectrum analyzer to characterize the emission and identify the frequency of the maximum emission, but do not have the ability to view the meters and the swept display simultaneously. The N9038A MXE has a Global Center Frequency option which links the center frequency across all instrument modes, ensuring an easy transition between meters and spectrum analysis.

– Combined meters and swept view: Some receivers allow simultaneous view of the meters and a limited swept view. The limited swept view is typically an FFT of the receiver intermediate-frequency (IF) that can be viewed using a single detector within a fairly narrow span (typically < 10MHz) and with a limited selection of resolution bandwidths. The MXE has a feature called Monitor Spectrum which allows users to see both the meters and a swept view while they are updated actively.

Time domain scanning

Time Domain scanning is an optional methodology for collecting pre-scan information prior to making final measurements. Unlike traditional frequency scanning (where the receivers' local oscillator is swept or stepped in small increments through the desired frequency range), time domain scanning uses high-overlap FFTs to collect amplitude information in larger frequency increments. The benefit to the user is shorter data collection time when using longer dwell times. CISPR-based standards require measurement dwell times that are inversely-proportional to the repetition rate of the measured emissions (for example, if the impulsive emission has a 100 Hz repetition frequency, users need to measure with a 10 millisecond dwell time). Frequency scanning requires that the user dwell the required time in each measured 6 dB resolution bandwidth (typically 200 Hz, 9 kHz or 120 kHz, as specified by CISPR). Time Domain scanning allows the user to dwell only once per FFT bandwidth, which is typically between 5 MHz and 20 MHz. While the time saved using time domain scanning varies with the required measurement methodology, the savings can be significant.

Amplitude distribution function (APD)

Amplitude Distribution Function, or APD, is a measurement of the probability of the signal amplitude as a function of time at a given frequency. APD is an optional measurement function being considered in CISPR 11 for emissions above 1 GHz.

Built-in diagnostic tools

If, after making measurements, you find that the signals are failing the limit, then the sources of the problem signals need to be located and repaired. The N9038A MXE EMI receiver has built-in diagnostic tools which greatly facilitate this work.

Spectrum analyzer

One of the most powerful diagnostic tools available is the built-in spectrum analyzer. With the built-in spectrum analyzer comes global center frequency, a variety of one-button power measurements, and more.

When the global center frequency feature is turned on, the center frequency of the EMI receiver and the built-in spectrum analyzer are the same. This is useful when a signal is found with the receiver and needs to be further investigated with the spectrum analyzer. After switching from receiver mode to spectrum analyzer mode, the user can zoom in on the signal of interest by narrowing the span. After zooming in, the center frequency can be adjusted to match that of the signal. Then, after switching back to the receiver mode, the old center frequency can be replaced with the new one. The last step is to, perform the final measurement with the EMI detectors.

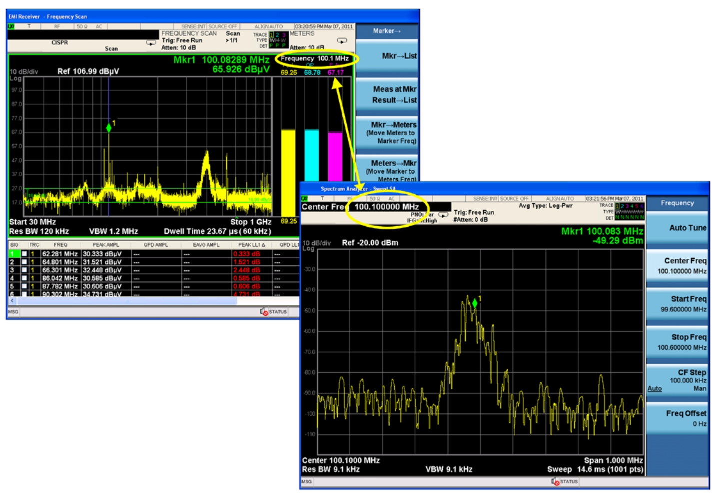


Figure 3. Gain insights about signals by switching between spectrum analyzer and EMI receiver modes while maintaining center frequency.

Also available in spectrum analyzer mode are the one-button power measurements which allow the user to make common RF measurements very quickly, and with little to no setup, with the push of a button. Measurements include channel power, occupied bandwidth, harmonics, and more.

Another measurement available with some EMI receivers and spectrum analyzers is real-time spectrum analysis (RTSA). RTSA differs from traditional swept-tuned measurements in that the LO is fix-tuned to the desired center frequency, and the span of the measurement is limited to the instantaneous acquisition bandwidth supported by the digitizer in the IF. There is no dead time between acquisitions and the process is continuous so that all sampled data is processed. This can be very useful for troubleshooting during pre-compliance but is not required to make compliance measurements. When it comes to pre-compliance, RTSA is useful in very specific diagnostic applications (such as capturing fast intermittent signals) but is usually not needed for the majority of EMI problems (e.g. shielding issues, cross-talk, high signal levels, etc.).

Strip chart

Many EMC tests require the user to rotate (normally using a turn-table) the DUT until they find the point of maximum radiation and use that value to measure against the limit. Assuming the turntable is rotating the DUT at 1 RPM, 15 seconds corresponds to the DUT being rotated by 90° and 30 seconds corresponding to a 180° rotation.

$$1\ RPM = \frac{360^\circ}{minute} \rightarrow 90^\circ \text{ in 15 seconds}$$

How does the user find the point of maximum radiation fast? The strip chart measurement enables the user to simultaneously measure 3 EMI detectors and plot the measurement over time. By visually inspecting the plot, the user is able to quickly find the angle of maximum radiation and measure it.

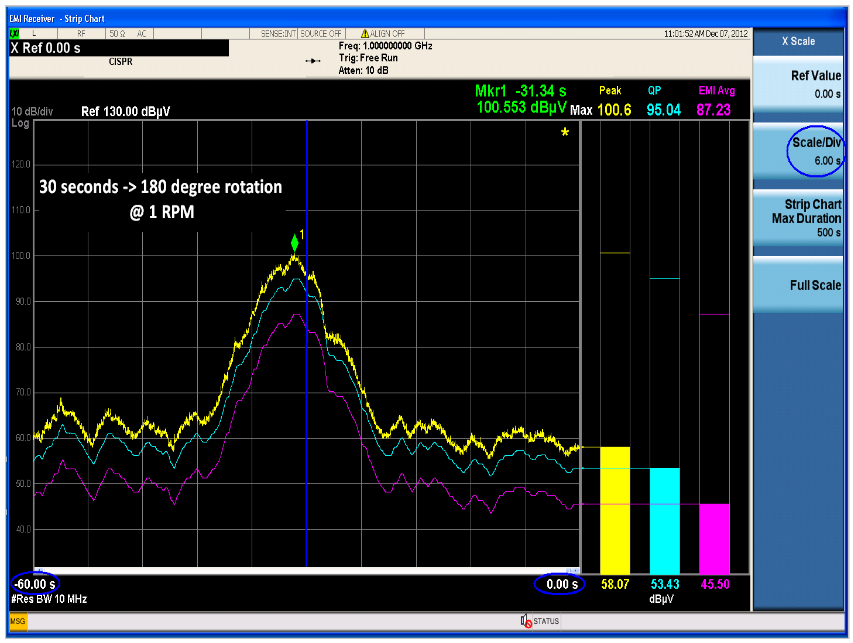


Figure 4. MXE EMI receiver strip chart measurement display.

The Strip Chart is also very useful in measuring according to the CISPR 16 measurement methodology. For emissions that are not steady, CISPR 16 states that the reading on the receiver be observed for at least 15 seconds for each measurement and then the highest readings shall be recorded. If the emission varies by more than 2 dB in the 15 second period, then the emission must be observed for a longer period. The Strip Chart is of great benefit in this case because it plots the emission over time as well as capturing the highest reading via the meters display.

The Strip Chart measurement is very similar to that of an oscilloscope. Up to 2 hours of data can be recorded and displayed.

Spectrogram

Another useful diagnostic tool is the spectrogram. With the spectrogram you can easily discriminate between continuous and intermittent signals by measuring the periodicity of the intermittent signals. The frequency and the time between signals can give greater insight as to where the signal is generated. Armed with this information, you can then use close field probes to pinpoint the emissions.

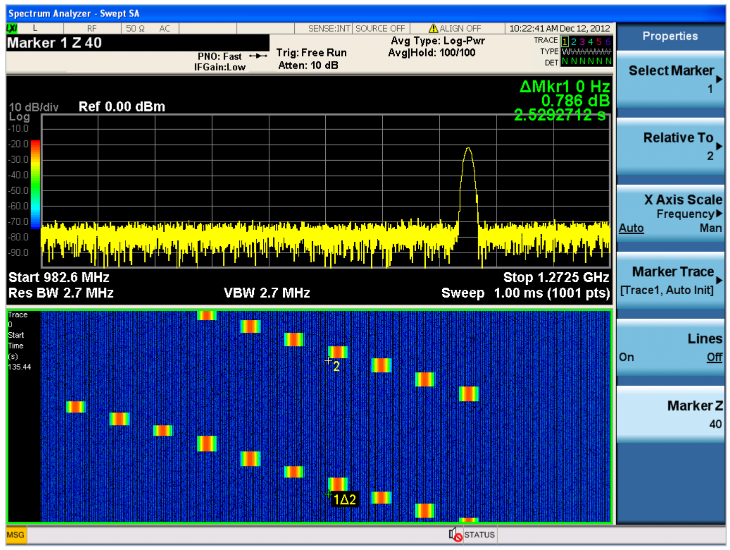


Figure 5. MXE EMI receiver spectrogram display.

Report generation

After your device's emissions have been measured, a report will most likely need to be created. This report may need to be sent to your R&D team to help them fix an emissions problem or to a customer if you operate a commercial EMC test facility.

The N9038A MXE EMI receiver is capable of generating a report detailing the test results. The report can be customized to include selected items such as trace data, signal list, limits, correction factor and screen, along with header information.

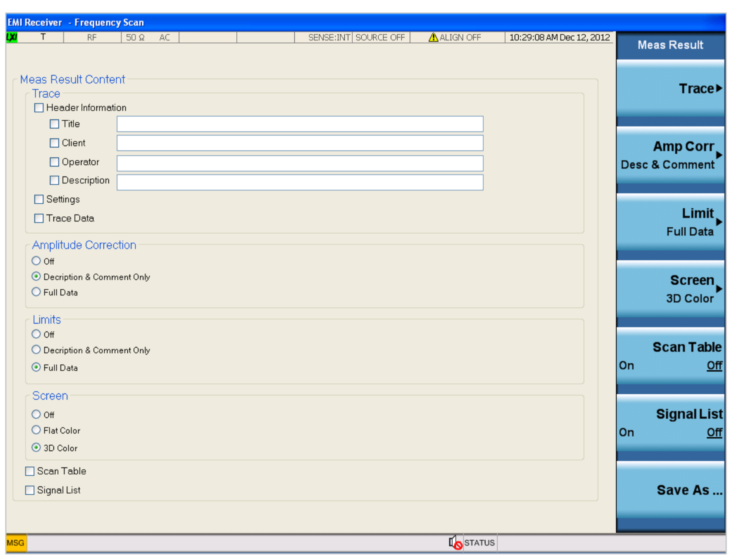


Figure 6. MXE EMI receiver report generator.

Conclusion

Engineers making compliance certification measurements are required to use measuring receivers that comply with the requirements of the appropriate measurement standard.

In addition to the key compliance requirements, there are also essential features, such as limit lines, margins, correction factors, and signal lists that define a receiver's usability. Of great benefit are diagnostic tools such as the built-in spectrum analyzer, strip chart, and spectrogram which aid in the identification and isolation of emissions problems.

Related Literature

MXE X-Series EMI Receiver N9038A, Brochure, Literature Number 5990-7422EN

N9038A MXE EMI Receiver 20 Hz to 8.4 and 26.5 GHz, Data Sheet,
Literature Number 5990-7421EN

Making EMI Compliance Measurements, Application Note, Data Sheet,
Literature Number 5990-7420EN

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