Interpreting EMI receiver specifications

Any instrument that meets all the requirements of CISPR 16, Part 1 is, by definition, an EMI receiver and can be used for compliance testing.

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Most commercial EMI standards reference CISPR Publication 16, Part 1 as the standard specifying the instrumentation for EMI and EMS measurements. This article will discuss the most important receiver specifications, summarize anticipated additional specifications, and discuss certain limitations of spectrum analyzers when used for compliance measurements.

An amendment to CISPR 16, Part 1 is also underway, which extends specifications to the 1 GHz-to-18 GHz range. It is discussed in this article as well.

The current version of CISPR 16, Part 1, dated August 1993, calls out receiver specifications for the frequency range from 9 kHz to 1 GHz. The document covers input impedance, detector characteristics, and intermediate frequency (IF) bandwidth shapes. Also specified is the amplitude accuracy for measuring sine waves and pulses with varying repetition rates. Complementing the receiver specification section are additional requirements for spurious responses, image and IF rejection, intermodulation distortion and screening effectiveness.

RECEIVER SPECIFICATIONS PER CISPR 16, PART 1 (08-93)

INPUT IMPEDANCE

The receiver input impedance is specified to be 50 ohms; the acceptable deviation from this nominal value is given as a VSWR (Voltage Standing Wave Ratio). Since a well-matched input attenuator improves the receiver's VSWR, this specification is given for two different attenuator settings: 0 dB and 10 dB or greater. This specification also contributes directly to the overall uncertainty of EMI measurements.

RESOLUTION BANDWIDTHS

Specific resolution bandwidths are called out for measurements in different frequency ranges. In general, receiver IF filters are usually specified by a bandwidth (for example, a 3-dB bandwidth) along with additional information about its frequency response, which can either be the shape factor of the filter (for instance, the ratio of a 60-dB to a 3-dB bandwidth) or a mask (Figure 1) in which the frequency response has to fit. CISPR 16, Part 1 calls out the 6-dB bandwidth values:

- 200 Hz for the 9 kHz to 150 kHz range
- 9 kHz for the 150 kHz to 30 MHz range
- 20 kHz for the 30 MHz to 1 GHz range

Furthermore, for each of these filters, a mask is given showing the insertion loss versus frequency offset from the filter's center frequency. Due to the specification as a mask, the IF filter's amplitude response is completely defined. Therefore, this specification is much more useful than a simple 6-dB bandwidth specification, which ignores the filter's amplitude response altogether. The filter mask specification ensures that both narrowband and broadband signal amplitudes can be com-

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pared directly without the need for data normalization to eliminate different filter responses. It should be noted that certain tolerances are allowed which can impact the measurement result of broadband signals, especially when peak detection is used.

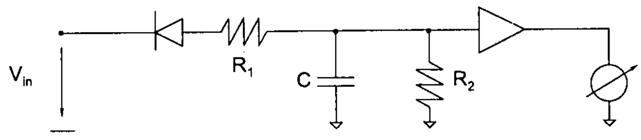

Figure 2. Block diagram of quasi-peak detector.

Detection Modes and Amplitude Accuracy

Quasi-peak detection serves as a reference for specifying the receiver's response to impulse signals when employing peak and average detection. The quasi-peak detector is defined in terms of electrical charge time, electrical discharge time and a mechanical time constant of a critically-damped indicating instrument. These time constants determine the circuit elements of the quasi-peak circuit (Figure 2). The mechanical meter is often simulated electronically in modern EMI receivers by a second-order low-pass filter with appropriate rise time and damping. The time constants differ between the various frequency ranges and determine the dwell time or scan time in each band. The specified time constants for the various frequency ranges are listed (Table 1).

The quasi-peak detector introduces weighting on the input signal according to its repetition rate, as mentioned. For peak detection, the minimum ratio of discharge time constant to charge time constant is defined. This ratio ensures that the peak indication is within 10 percent of the true peak value of a signal with a 1-Hz frequency.

The amplitude accuracy specification of any EMI receiver consists of multiple parts. First, the quasi-peak measuring receiver must be able to measure a sine wave amplitude (supplied by a source with a 50-ohm output impedance) with a deviation less than 2 dB from the original value. Second, the responses of the quasi-peak receiver are compared to an impulse with defined spectral intensity, repetition rate and spectrum uniformity, and a sine wave with defined amplitude. Both results have to be within 1.5 dB, referenced to the sine wave level. Third, pulses with the same characteristics as those mentioned above, but with varying repetition rates, are applied to the quasi-peak receiver.

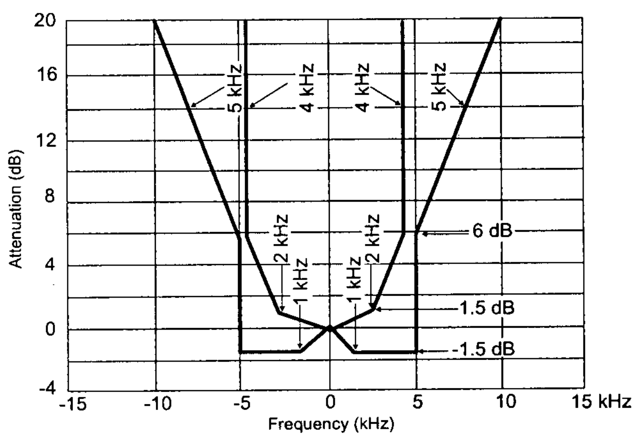

Figure 1. Limits of overall receiver passband selectivity for Band B (150 kHz–30 MHz).

A table is given in CISPR 16, Part 1, Section 2.4.2, specifying the required amplitude change and allowable deviations as a function of the repetition frequency. The amplitude changes are referenced to the values obtained in the second step. The specified amplitude changes are introduced by the quasi-peak detector. A pulse with a lower repetition frequency will cause a lower amplitude reading than a pulse with a higher frequency.

It should be noted that the signs in the table seem to indicate the opposite. This is because the specified amplitude variations represent a required change of signal generator amplitude to maintain a constant receiver reading. So, if the signal generator level remains unchanged, the receiver reading has to vary according to the values called out in the table. The test of the receiver's response to these pulses is a system check rather than a verification of a single receiver specification, because the required accuracy can be achieved only in the case of sufficient dynamic range and appropriate implementation of IF bandwidths, detector characteristics and preselection.

In this context, the receiver type is irrelevant; both fixed tuned and scanning receivers can meet these specifications. For peak and average measuring receivers, responses to both an impulse with defined spectral intensity and repetition rate and a sine wave with defined amplitude are compared. The two results have to be within a 1.5-dB variation, referenced to the sine wave level. The relative response to impulses is given as a ratio between peak and quasi-peak or quasi-peak and average indication respectively at the specified frequencies. In addition, the response of an average measuring receiver to repetitive pulses needs to follow the law:

$$\text{Amplitude} = \frac{1}{\text{Repetition rate}}$$

Screening Effectiveness

The specification for the immunity of EMI receivers is given in Section 2.8 of CISPR 16, Part 1. It addresses the ability of the receiver to operate in an electromagnetic field without degradation of its performance. The receiver needs to be able to make measurements in an electromagnetic field of 3 V/m unmodulated at any frequency in its measurement range up to 1 GHz. The

FREQUENCY RANGE	9 kHz - 150 kHz	150 kHz - 30 MHz	30 MHz - 1000 MHz
Detector electrical charge time constant [ms]	45	1	1
Detector electrical discharge time constant [ms]	500	160	550
Mechanical time constant of a critically-damped indicating instrument [ms]	160	160	100

Table 1. Quasi-peak detector time constants.

maximum error introduced must not exceed 1 dB over the whole indication range. Exceptions are permissible, but those frequencies where the 1 dB margin is exceeded need to be clearly stated.

Rejection of IF Frequency, Image Frequency, and Other Spurious Signals

The ratio of an input sine wave at the IF frequency, image frequency or other frequency to that of a sine wave at the tuned frequency that produces the same receiver reading must not be less than 40 dB. RF preselection is usually required to meet these specifications.

Other specifications (such as intermodulation distortion and effects of random noise) complete the overall description of EMI receivers. It is important to understand that these specifications define an EMI receiver. Any instrument that meets all the requirements is, by definition, an EMI receiver and can be used for compliance testing. The actual implementation—be it fixed-tuned or scanning—is not mentioned in the document and is not relevant.

EMI Receiver Specifications for Measurements Above 1 GHz

Sometime in 1999, a second amendment to CISPR 16, Part 1 will be published and go into effect. Among the additions to the document are specifications for receivers and spectrum analyzers which will be introduced for the frequency range from 1 GHz to 18 GHz. While the spectrum analyzer is viewed as the instrument which is most commonly used for measurements above 1 GHz, the use of measuring receivers with stepped frequency scanning is not excluded.

Resolution Bandwidth

Generally, the resolution bandwidth of the measuring receiver is specified to be 1 MHz. However, product standards like CISPR 11 (for ISM, or Industrial, Scientific, and Medical Equipment) or CISPR 22 (for ITE, or Information Technology Equipment) may call out narrower or wider resolution bandwidths, depending on the system to be protected, the emission source and the applicable emission limit. Regardless, the specified bandwidth must have a tolerance of 10 percent. In addition, the bandwidth specification is the impulse bandwidth of the filter, and not the 6 dB bandwidth. This allows for the direct comparison of measurement data taken with different filters, independent of the frequency and phase response.

IF Detector

The peak detector is the preferred detector for measurements above 1 GHz. In case time-varying signals need to be measured, a display maximum hold function should be used to capture the maximum amplitude. Additional measurements with a weighting detector may also be required by product standards (for instance, as called out in CISPR/B/204/CDV, September 1998). The weighting can be achieved by reducing the video bandwidth of the spectrum analyzer.

Video Bandwidth

For measurements with the peak detector, the video bandwidth is to be set to a value higher (a minimum of three times higher) than the resolution bandwidth, which is typically specified to be 1 MHz. To achieve weighted measurements, the video bandwidth should be set to a value lower than the modulation bandwidth of the signal to be measured. Evaluation of the correct video bandwidth can be done by reducing its setting until the indicated amplitude changes by less than approximately 1 dB. If the spectrum analyzer is used in linear amplitude display mode, the result will correspond to the average level of the measured signal. In case the logarithmic display mode is used, the result will correspond to the average of the logarithmic values of the measured signal.

Screening Effectiveness

As discussed, a specification for the immunity of EMI receivers is given in Section 2.8 of CISPR 16, Part 1 for the frequency range below 1 GHz, which addresses the ability of the receiver to operate in an electromagnetic field without degradation of its performance. This requirement for measurements above 1 GHz is currently under consideration, so no field strength value is specified.

Input Filtering

One or more filters must be provided at the input of the spectrum analyzer to provide sufficient attenuation at the fundamental frequency of certain equipment under test. This will avoid damage and overload of the analyzer's front-end, and prevent the generation of harmonic and intermodulation signals when measuring low-level signals in the presence of a strong fundamental signal.

Receiver Display

To permit visual observations while

using slower sweep times, the spectrum analyzer or EMI receiver also must provide some form of display storage.

CONSIDERATIONS FOR USE OF SPECTRUM ANALYZERS

All the specifications in CISPR 16, Part 1 mentioned in the first section define an EMI receiver for measurements in the frequency range from 9 kHz to 1 GHz. Any instrument that meets all the requirements is, by definition, an EMI receiver and therefore can be used for EMI compliance testing. The actual hardware implementation (fixed-tuned or scanning) is not mentioned in the document and is not relevant.

For measurements in the frequency range from 1 GHz to 18 GHz, the spectrum analyzer is the preferred instrument. A scanning receiver is often confused with a spectrum analyzer, largely because both instruments are continuously tuned over the frequency range of interest and provide a graphical display of the measured spectrum. The difference is that a scanning receiver meets all the specifications in CISPR 16, Part 1, so it is very well-suited for EMI compliance measurements and offers additional advantages over a fixed-tuned receiver. These requirements may not be met by a spectrum analyzer alone for the following reasons:

- Due to lack of preselection, overload may occur when measuring low-level signals in the presence of either broadband impulse signals such as clicks or power supply switching transients, or narrowband stationary or intermittent signals from broadcast transmitters and mobile radios.
- The instrument's resolution bandwidths and IF filter shapes may differ from those specified by CISPR (that is, 200 Hz, 9 kHz, 120 kHz), and therefore, the peak amplitude of broadband signals cannot be compared to limit lines called out in commercial EMI standards.
- Quasi-peak detection and the associated mechanical meter response characteristics may not be provided with the spectrum analyzer, so broadband signals cannot be evaluated with the proper weighting.
- The sensitivity of the spectrum analyzer alone may be insufficient to accurately measure signals at the compliance limit levels.
- The amplitude error for sine wave measurements may be greater than the specified 2 dB.

SUMMARY

The hardware architecture of spectrum analyzers and EMI receivers has many commonalities: both instruments are superheterodyne receivers and measure signal voltages in a frequency-selective way. EMI receivers have additional stages to meet certain specifications called out in CISPR 16, Part 1. All the relevant specifications have been discussed. If an instrument meets all these criteria, it can be used for compliance measurements. There is no specification that a receiver must use a stepped or swept approach. Also, no reference is made regarding the indicator of measurement results: both numerical and graphical presentations of the test data are acceptable. In addition, no numbers are called out for the required dynamic range or actual sensitivity. These critical specifications are included in the amplitude accuracy specification for the measurement of pulses with varying repetition rates. Therefore, both scanning and stepped receivers are equally suitable for making EMI compliance measurements.

Spectrum analyzers, on the other hand, are the preferred instruments for measurements between 1 GHz and 18 GHz. However, they typically don't meet all requirements called out in CISPR 16, Part 1 for the frequency range below 1 GHz. Consequently, their use for compliance testing in the frequency range below 1 GHz is limited.

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