Making Compliance Measurements with the N9039A-Based EMI Measurement Receiver

Application Note

Agilent Technologies

Table of Contents

1.0 Introduction to compliance measurements

Note: In this application note, detailed measurement procedures are provided for Agilent Technologies EMI receivers.[1]

Any product that uses the public power grid or has electronic circuitry must pass EMC (electromagnetic compatibility) requirements. These requirements fall into four broad types of testing: radiated and conducted emissions testing, and radiated and conducted immunity testing.

Conducted emissions testing focuses on signals present on the AC mains that are generated by the equipment under test (EUT). The frequency range of these measurements is typically 9 kHz to 30 MHz.

Radiated emissions testing looks for signals being emitted from the EUT through space. The typical frequency range for these measurements is 30 MHz to 1 GHz, although FCC regulations require testing up to 200 GHz for an intentional radiator (such as a wireless transmitter) operating at a center frequency above 30 GHz.

Figure 1 illustrates the difference between *radiated emissions, radiated immunity, conducted emissions,* and *conducted immunity*. Radiated immunity is the ability of a device or product to withstand radiated electromagnetic fields. Conducted immunity is the ability of a device or product to withstand electrical disturbances on power or data lines. Immunity testing will not be covered in this document.

For an electromagnetic compatibility problem to occur (such as when an electric drill interferes with TV reception), there must be a generator or source, a coupling path and a receptor. Until recently, most efforts to remove EMC problems have focused on reducing the emissions of the source to an acceptable level.

1. EMI receiver consists of E4440A Series PSA limit line disk, N9039A preselector and a signal source

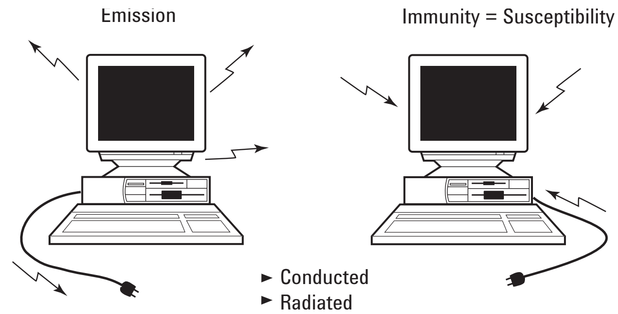


Figure 1. Four types of EMC measurements

2.0 The compliance measurements process

Before compliance measurements can be performed on a product, some preliminary questions must be answered:

1. Where will the product be sold (i.e., the United States, Europe, Japan)?

2. What is the classification of the product (i.e. information technology equipment (ITE); industrial, scientific or medical (ISM); automotive and communications)?

3. Where will the product be used (i.e., home, commercial, light industry or heavy industry)?

With the answers to the above questions, you can determine which testing requirements apply to your product by referring to Tables 1a and 1b below. For example, if you have determined that your product is an information technology (ITE) device and you will sell it in the U.S. then you need to test the product to FCC part 15 regulations.

International regulations summary (Emissions)

CISPR	FCC	EN's	Description
11	Part 18	EN 55011	Industrial, scientific and medical
12	(SAE)		Automotives
13	Part 15	EN 55013	Broadcast receivers
14		EN 55014	Household appliances/tools
15		EN 55015	Fluorescent lights/luminaries
16-1-1			Measurement apparatus/methods
22	Part 15	EN 55022	Information technology equipment
		EN 50081-1,2	Generic emissions standards

Table 1a. Comparison of regulatory agency requirements.

European Norms (EN)

Equipment type	Emissions
Generic equipment	EN 50081-1
Residential	
Light industrial	
Industrial	EN 50081-2
Information technology equipment (ITE)	EN 55022
Industrial, scientific, medical products (ISM)	EN 55011

Table 1b. Major European requirements

European Norms

EN55011 (CISPR 11)

Industrial, scientific, and medical products

Class A: Used in establishments other than domestic areas
Class B: Suitable for use in domestic establishments

Group 1: Laboratory, medical, and scientific equipment. (For example, signal generators, measuring receivers, frequency counters, spectrum analyzers, switching mode power supplies, weighing machines, and electronic microscopes.)

Group 2: Industrial induction heating equipment, dielectric heating equipment, industrial microwave heating equipment, domestic microwave ovens, medical apparatus, spark erosion equipment, and spot welders. (For example, metal melting, billet heating, component heating, soldering and brazing, wood gluing, plastic welding, food processing, food thawing, paper drying, and microwave therapy equipment.)

EN55014 (CISPR 14)

Electric motor-operated and thermal appliances for household and similar purposes, electric tools, and electric apparatus. Depending on the power rating of the item being tested, use one of the limits shown here:

	Agilent* file names
EN55014 Conducted household Appliances QP	EN14CHAQ.lim
EN55014 Conducted household Appliances AVE	EN14CHAA.lim
EN55014 Conducted < 700 W motors QP	EN14Cx7Q.lim
EN55014 Conducted < 700 W motors AVE	EN14Cx7A.lim
EN55014 Conducted > 700 W < 1000 W motors QP	EN14Cx1Q.lim
EN55014 Conducted > 700 W < 1000 W motors AVE	EN14Cx1A.lim
EN55014 Conducted > 1000 W Motors QP	EN14C1xQ.lim
EN55014 Conducted > 1000 W Motors AVE	EN14C1xA.lim
EN55014 Radiated household Appliances QP	EN14RHAQ.lim
EN55014 Radiated household Appliances AVE	EN14RHAA.lim
EN55014 Radiated < 700 W motors QP	EN14Rx7Q.lim
EN55014 Radiated < 700 W motors AVE	EN14Rx7A.lim
EN55014 Radiated > 700 W < 1000 W motors QP	EN14Rx1Q.lim
EN55014 Radiated > 700 W < 1000 W motors AVE	EN14Rx1A.lim
EN55014 Radiated > 1000 W Motors QP	EN14R1xQ.lim
EN55014 Radiated > 1000 W Motors AVE	EN14R1xA.lim

Note: The conducted range is 150 kHz to 30 MHz and the radiated range is 30 MHz to 300 MHz.

EN55022 (CISPR 22)

Information technology equipment

Equipment with the primary function of data entry, storage, displaying, retrieval, transmission, processing, switching or controlling. (For example, data processing equipment, office machines, electronic business equipment, and telecommunications equipment.)

Class A ITE: Not intended for domestic use.
Class B ITE: Intended for domestic use.

FCC (Federal Communications Commission)

Equipment	FCC
Broadcast receivers	Part 15
Household appliances/tools	
Fluorescent lights/luminaries	
Information technology equipment (ITE)	
Industrial, scientific, medical products (ISM)	Part 18
Conducted measurements: 450 kHz - 30 MHz	
Radiated measurements: 30 MHz - 1000 MHz, 40 GHz	

Table 1c. FCC regulations

*The Limit lines and correction factors can be downloaded from **www.agilent.com,** search on EMI measurement receiver.

Federal Communications Commission
FCC Part 15
Radio frequency devices-unintentional radiators
(For example, TV broadcast receivers, FM broadcast receivers, CB receivers, scanning receivers, TV interface device, cable system terminal device, Class B personal computers and peripherals, Class B digital devices, Class A digital devices and peripherals, and external switching power supplies).

Class A digital devices are marketed for use in a commercial, industrial or business environment.

Class B digital devices are marketed for use in a residential environment.

For assistance, call the agency for conformation of the applicable requirement. (A list of phone numbers is included in Appendix E).

3.0 Compliance EMI receiver requirements

There are several requirements for making compliance EMI measurements. The first is an EMI receiver that meets CISPR 16-1-1.[1]

A CISPR 16-1-1 receiver must have the following functionality in the range 9 kHz - 1000 MHz:

- Amplitude accuracy:
  Nominally a ±2 dB absolute amplitude accuracy is required
- Specified bandwidths:
  CISPR specifies the following bandwidths (6 dB):

Bandwidth	Frequency range
200 Hz	9 kHz to 150 kHz
9 kHz	150 kHz to 30 MHz
120 kHz	30 MHz to 1000 MHz

The frequency response of the filters must also fall within a "mask" defined by CISPR 16-1-1.

- Specified detectors: Peak, quasi-peak, and average (see Appendix D for a description of these detectors). The charge, discharge time and meter constants of the quasi-peak detector are specified.
- Specified input impedance, nominal value of 50 ohms; deviations specified as VSWR.
- Pass product immunity in a 3 V/m field.
- Ability to pass the "CISPR pulse test."
- Other specific harmonic and intermodulation requirements.

The CISPR pulse test consists of broadband pulses of a defined spectral intensity of varying repetition frequency presented to the EMI receiver. The quasi-peak detector must measure these pulses at a specific level within a specified accuracy. In order to meet this pulse test, it is implied, but not specified, that the receiver must have:

- Preselection: Preselection is achieved by input filters that track the receiver tuning to reduce broadband noise overload at the front end mixer.
- Sensitivity and dynamic range. The EMI receiver must have a noise floor low enough to measure signals at low PRFs.

Note: Although high sensitivity and dynamic range capabilities are implied to meet the CISPR pulse test, actual numbers for these parameters are not specified.

A recommended feature for ensuring accurate measurements is overload detection. To make an accurate measurement, the receiver must be in linear operating mode and not be in saturation at the front-end mixer because of large narrowband signals or broadband emissions. A useful overload detection scheme will alert the user to overload conditions in all frequency ranges and in all modes of operation. An advanced overload detection and measurement scheme will "autorange", or automatically put in enough attenuation prior to the first mixer to measure the signal in non-overload conditions.

1. Comite International Special des Perturbations Radioelectriques

3.1 Requirements above 1 GHz:

FCC regulations and proposed CISPR regulations require a 1 MHz bandwidth for measurements above 1 GHz. The Agilent EMI receiver also meets these requirements.

In addition, no quasi-peak detector is required for measurements above 1 GHz. The CISPR pulse test is not required above 1 GHz, but high sensitivity in the measuring system is important to achieve sufficient dynamic range to perform the measurements.

According to current FCC regulations, the maximum test frequency is the fifth harmonic of the highest clock frequency for an "unintentional radiator" (for example, a computer) and the tenth harmonic for an intentional radiator (such as a cellular phone or wireless LAN).

4.0 Preparing conducted emissions measurements

Emissions testing is divided into conducted emissions and radiated emissions testing. Follow these steps to set up the equipment and the equipment under test.

4.1 Conducted test setup

ANSI C63.4 describes a specific test setup for conducted emissions. FCC Part 15 details the limits for these tests. Figure 2 shows a setup for a personal computer, requiring a test to CISPR 22 or FCC part 15 (Class B):

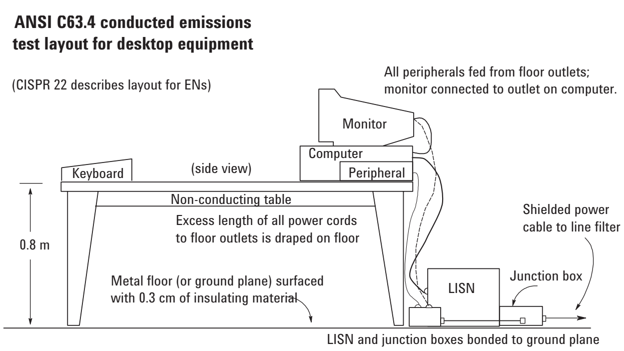


Figure 2. Side view of conducted test setup. The LISN output connects to the receiver.

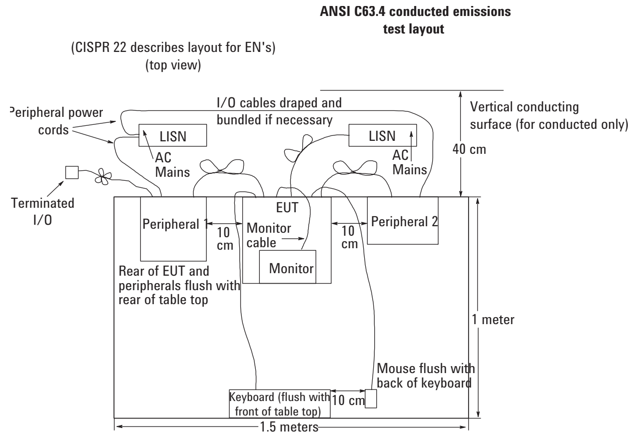


Figure 3. Top view of conducted test setup. The LISN output connects to the receiver.

CISPR 22 shows a similar conducted test setup for EuroNorms (ENs).

Interconnect the EMI receiver, LISN and EUT as shown in Figure 3. The function of a LISN is detailed in Appendix A.

Note: The setup does not include a separate transient limiter for transient protection. It is recommended that a transient limiter be used.

4.2 Configuring the receiver

Note: The following sequence of steps for making a compliant measurement with the EMI measurement receiver assumes that the measurement setup and measuring receiver are compliant with the applicable standard and a system alignment has been completed if required.

1. Disconnect the input to the receiver.

2. Set up the correct frequency range by pressing [Mode], <EMC analyzer> [mode setup], <EMI presets>, <CISPR B, 130 kHz to 30 MHz>. The EMI receiver automatically selects the correct CISPR bandwidth. Select <use RF preselector yes> if not selected.

3. Based on the type of equipment and the regulatory agency requirements, select the limit line on the EMI receiver. Selecting and loading limit lines is accomplished as follows:

   Insert supplied disk
   Load EN55022 conducted QP
   Press [File], <Load>, <TYPE Limit>
   <Select Dir A> scroll to <EN22BCQP>
   <Load now>

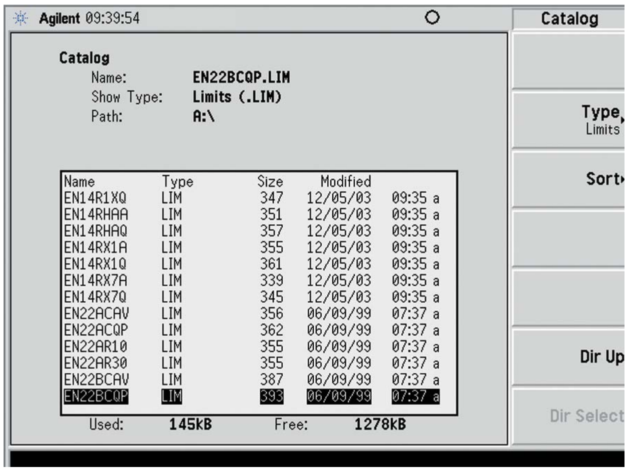


Figure 4. Loading limit lines for an EN55022 conducted test

4. Next, load correction factors for the LISN by pressing the following keys:

[File], <Load>, <Type> <Corrections>, <11967D>, <Load now>

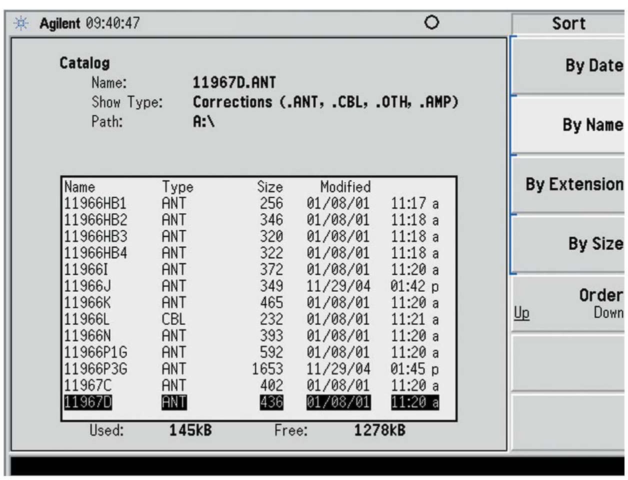


Figure 5. Loading correction factors for a LISN

After loading the LISN correction factors and limit lines, your display should look something like Figure 6:

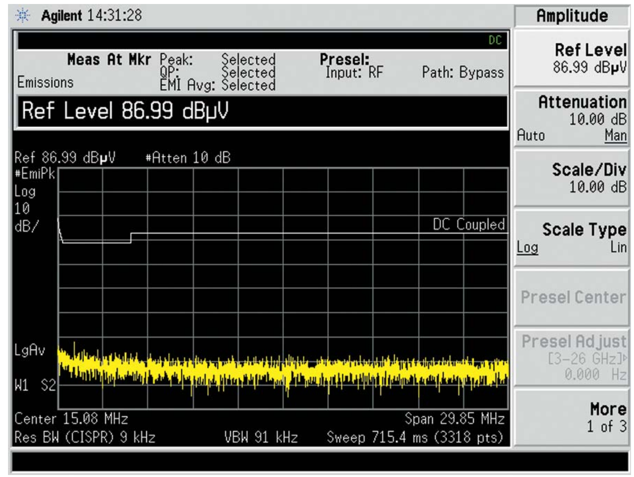


Figure 6. Display corrected for LISN and QP limit line on

Switch to Filter mode [input/output], <Preselector Path Filter>

4.3 Performing conducted emissions measurements

At this point the EMI receiver is set up with all the correct parameters, including bandwidth, frequency range, LISN compensation and limit line. There is one more thing to consider before starting conducted measurements, which is the effect of the ambient environment on the results. The power cable between the LISN and the EUT can act as an antenna, which can cause false EUT responses on the display. To test that this phenomenon is not occurring, switch the EUT off and check the display to insure that the noise floor is at least 6 dB below the limit line. (See Figure 7).

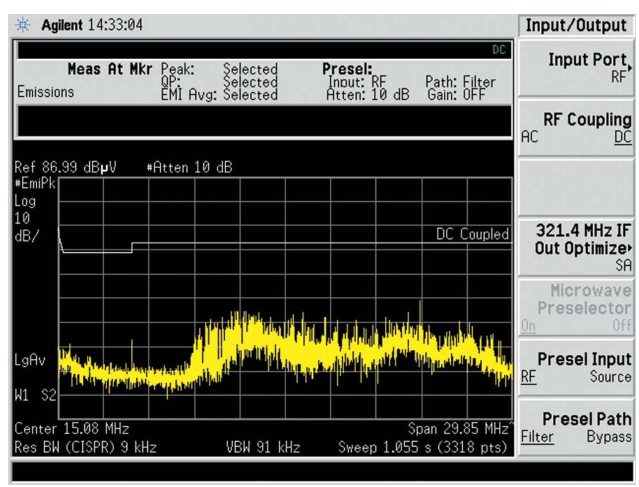


Figure 7. A conducted test in an ambient environment

Switch the power to the EUT on and observe the display. If there are no signals above the limit line, then your job is done and your product passes the conducted emissions limit. Data and signals close to the limit may need to be collected for your report. Remember that line and neutral must be tested. If there are signals above the limit, closer analysis is needed.

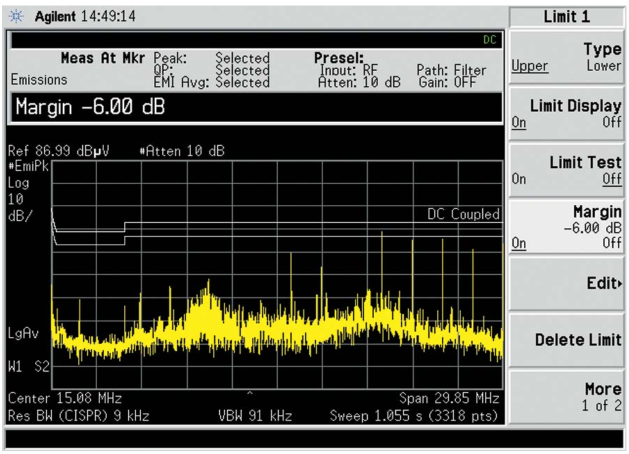


Figure 8. Conducted failure

The next step is to perform a quasi-peak measurement on signals above the limit line. One method is to use the “measure at marker” function.

Before measuring, make sure you have selected the correct detectors. Press [Meas Setup], <Meas at Marker detector>, <QP on>, <EMI Avg on>.

The unique Zoom feature of the EMI measurement receiver allows you to look at an active broad span trace while zooming in on a portion of the trace for a closer look. Both traces remain active. The broad span has a cursor indicating the center frequency of the zoomed trace. The highlighted trace can make use of many of the EMI measurement receiver features such as frequency, amplitude and marker functions. Change the highlighted trace by pressing [Next Window].

To measure the peak, quasi-peak and average level of a signal, perform the following:

1. Press [Zoom] highlight the lower window by pressing [Next Window]. Zoom in on signals. Press [Frequency] and use the knob to go to signals of interest.

2. Press [marker] and use the knob to select signal to be measured.

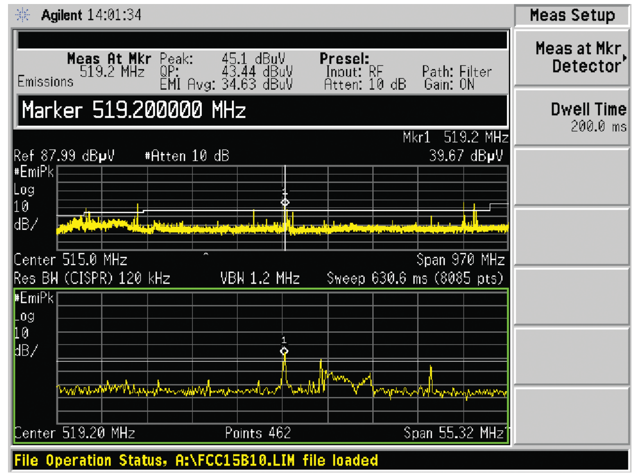


Figure 9. “Windows” function, zooming in on signals

3. Press [Marker Fctn], <Measure at Mkr>. After the measurement is completed, the signal frequency and amplitude will appear in the box above the display. Record the measurement.

Repeat the measurement procedure until all the signals above the limit line have been measured.

At this point, all the measured signal values have been recorded.

The product passes its test if:

no measured quasi-peak values are above the quasi-peak limit, and no measured average values are above the average limit,

or

no measured quasi-peak values are above the average limit.

Remember that all lines (i.e. line and neutral) must be tested.

If some of the values are above the quasi-peak level using the quasi-peak detector and also above the average limit with the average detector, then some troubleshooting and redesign is required.

5.0 Preparing for radiated emissions measurements

Performing radiated emissions measurements is not as straight-forward as performing conducted EMI measurements. There is the added complexity of the open air ambient environment, which can interfere with the emissions from the device under test. Fortunately, there are methods to differentiate between signals in the ambient environment (for example, TV, FM and cellular radio).

5.1 Open site requirements

EUTs are measured in an open area test site (OATS). ANSI C63.4 and CISPR 16-1-1 specify the requirements for an OATS, including:

- Preferred measurement distances of 3, 10 and 30 meters.
- Antenna positioning at 1 to 4 meter heights.
- An area called the "CISPR ellipse" of major diameter 2X and minor diameter $\sqrt{3} \cdot X$, where X is the measurementdistance. The ellipse must be free of any reflecting objects.
- A metal ground plane for the measurement area.

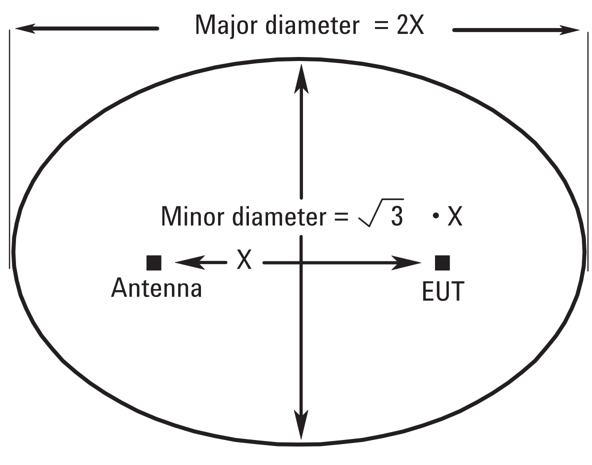


Figure 10. The CISPR ellipse

- The OATS must pass a "normalized site attenuation" test, or NSA. The NSA is a test that determines what value a wave from a transmitting antenna (the EUT) is attenuated by the receiving antenna located on the antenna tower, referenced to a signal directly transmitted (via cable). Note that what is received at the receiving antenna is a combination of direct waves and reflected waves. The wave attenuation of the OATS must fall within a specified accuracy band. The test is performed at a distance where the compliance tests will be performed.

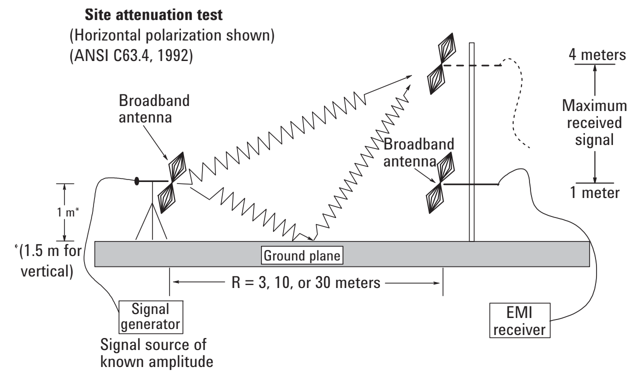


Figure 11. NSA procedure schematic, horizontal polarization

For complete details on OATS requirements, see CISPR 16-1-1 and ANSI C63.4., and ANSI C63.7. ANSI C63.7 describes OATS construction.

Note: 10 meter anechoic chambers and GTEM cells can also be used for radiated compliance measurements.

5.2 Radiated emissions test setup

Note: The following sequence of steps for making a compliant measurement with the analyzer assumes that the measurement setup is compliant with the applicable standard.

1. Arrange the antenna, EUT and EMI receiver as shown in Figure 12. Separate the antenna and the EUT by 3 meters (10 meters if the regulation calls it out). CISPR and ANSI require your EUT to be in worst case mode of operation (i.e. attached cables, monitor).

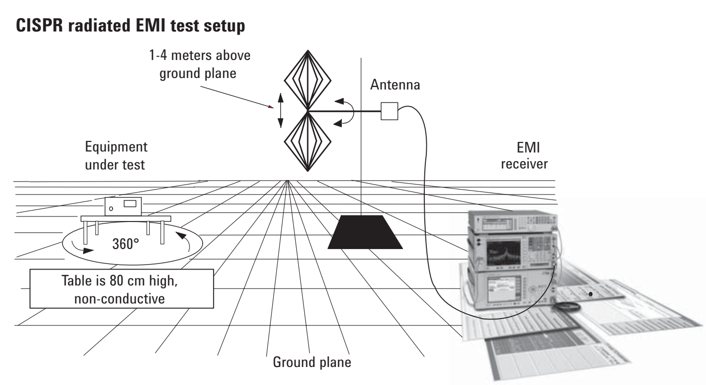


Figure 12. Radiated test setup

2. Use Table 1 (page 4) to determine the regulation that your product must be tested to.
3. Set up the EMI receiver for the correct span, antenna correction factors, and limit line with a margin. In this case, we are testing to the FCC part 15, class B 3 meter limit. Load in the appropriate limit line using the following steps:

   [File], <Load>, <type>, <Limits>.

Scroll down to the radiated emissions limit determined in Table 1 (i.e., FCC15B3).

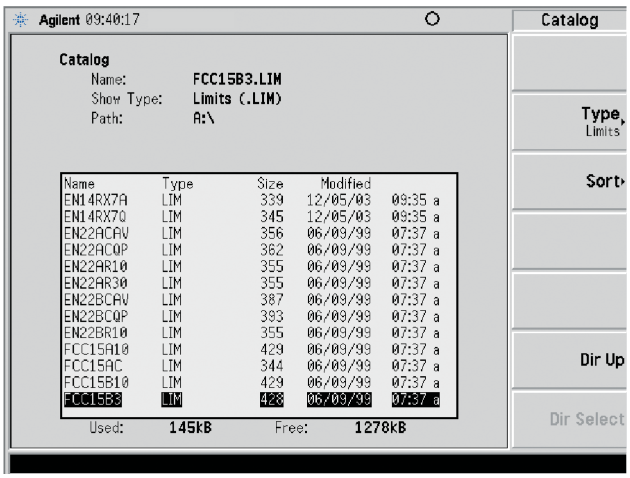


Figure 13. Loading FCC 3-meter class B limit

4. Press <LOAD Now>.

5. Load the appropriate antenna correction factors. The Agilent EMI receiver has three preset radiated emissions test bands, 30 MHz to 300 MHz, 300 MHz to 1 GHz, and 30 MHz to 1 GHz. The 30 MHz to 300 MHz band uses a biconical antenna and the 300 MHz to 1 GHz band uses a log periodic antenna. There is also a broad band antenna (11966P), which covers 30 MHz to 1 GHz.

   [File], <Load>, <TYPE>, <corrections>

   Scroll down to the antenna you wish to use (11966P1G) with the knob or the up/down arrows.

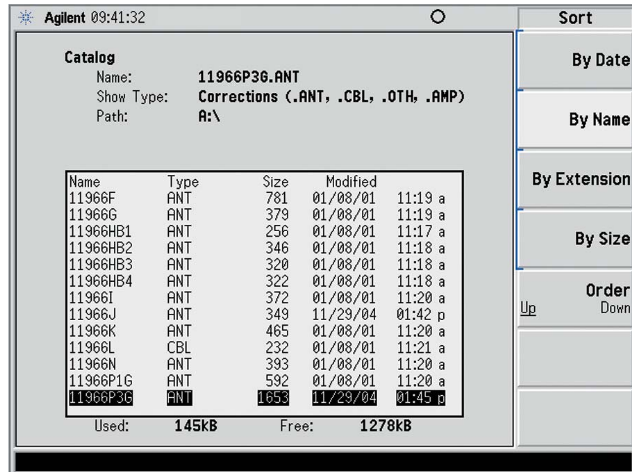


Figure 14. Loading correction factor for broadband antenna

   Press <LOAD Now>.

Typical antenna factors are now loaded into the EMI receiver. The display is now corrected for the loss of the antenna and the level is measured in dBμV/m*, which is a field strength measurement. (See Appendix B for more information on field strength.) So far, you have arranged the equipment with the EUT 3 meters from the antenna, chosen the appropriate limit line and corrected the display for antenna loss.

5.3 Measuring radiated emissions

The next step is to evaluate the radiated emissions from your product. With the EUT off, sweep the frequency range of interest. This gives you a good idea of the ambient signal levels. The ideal situation is to have all the ambient signals below the limit line. In many cases they are not, so it's a good idea to measure and record them.

*To display the correct units, press [Amplitude], <more>, <Y Axis units>, <dbμV/m>

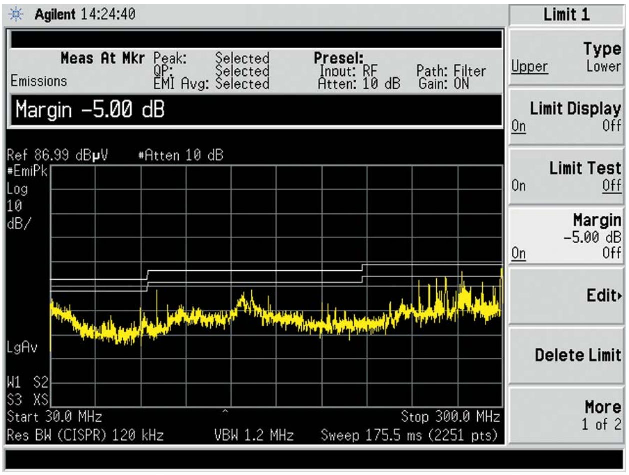


Figure 15. An ambient environment for radiated emissions. Ambients can often be above your limit line. 5.4 Ambient signal measurements

5.4 Ambient signal measurements

The process for measuring ambient signals is as follows:

1. Perform a max hold on the signals in the band by pressing [Trace], <max hold>. This process captures most signals including low PRF signals.

2. Use the zoom window to zoom in on a signal of interest which is above the limit line by pressing [Zoom], [Next window] to highlight the zoomed window. Then press [Frequency] and use the data entry knob to move the window to signals you wish to measure.

3. Place a marker on the signal to be measured. Press [Marker] and use the knob to adjust the marker. To measure the signal, press [Marker Fctn], <Measure at Marker>. The results are displayed at the top of the screen.

4. Record the frequency and amplitude of the signal, move the marker to the next signal above the limit line, perform a <Measure at Marker>, and record the results. After measuring all the signals above the limit, you have developed a list which you can compare against when measuring signals from your EUT.

5.5 Placement of EUT for maximum signals (manual measurement process)

Radiated emissions from electronic devices are not uniform. The strongest emissions may be from the rear panel or front panel or slots in the shielding. To insure that you are measuring the worst case emissions from your device, do the following:

1. With the EMI receiver adjusted to view the span of interest, move the EUT through a 360-degree rotation in 45-degree increments.

2. At each 45-degree step, note the amplitude of the largest signal. It is also recommended that the screen be copied to disk by pressing [File], <Save>, <Type>, <Screen>, <Name>, <position> for later reference and <Save Now>.

After all the screens have been captured, upload them to your computer into Paint or another convenient application so you can compare the screen captures side by side. In some cases, you may find that there are worst-case emissions for different frequencies at different positions. For example, you may find worst-case for 100 MHz emissions at 90-degrees, and at 270 degrees for 200 MHz. In this case, the emissions tests must be performed at both positions. If you are not sure whether the signal you are looking at is an ambient or EUT signal, switch off the EUT. An ambient signal will not change. Worst case emissions must be found for both horizontal and vertical antenna polarizations.

5.6 Ambient plus EUT measurements

Orient the EUT to one of the worst case positions. There may be more than one EUT position having emissions above the limit line. A quasi-peak measurement must be performed on each of these above-the-line emissions. If the quasi-peak measurement still indicates a failure, then some troubleshooting and repair is required. Use a close field probe such as the Agilent 11940A to isolate the location or source of the emission. The solution could be as simple as poor cable grounding or unwanted slots in the shielding.

If there are several signals above the limit that are not identified as ambient signals, it is recommended that you zoom in on one or two at a time, measuring the quasi-peak value of each. Below are two methods of measuring the quasi-peak value and comparing to a limit.

1. Place the marker on the highest signal and perform a <Measure at Marker>, Press [Peak Search], [Meas Setup], <Measure at Marker>. Compare the QP value to the value of the limit line at that frequency. If the QP level is less than the limit line value, you pass.

2. Another method of measuring the quasi-peak level of a signal is to place the marker on the signal of interest and have the marker moved to center frequency and go to zero span. Turn on the QP detector. If the end result is below the limit, then the emission passes. Press [Peak Search], [Marker →], <CF>, [Span], <Zero Span>, [Det], <Quasi-peak on>. The display is a flat line representing the QP of the signal. Press <Peak detector on> and [Span], <Last Span>.

Repeat one of the above processes for each of the EUT emissions captured during the rotation of the EUT. If you are in doubt as to whether the signal is an emission from your EUT, switch the power off. If the signal remains, it is an ambient signal. Another way to determine an ambient signal is its constant amplitude during EUT rotation. Sometimes it is not convenient to switch the power off on a EUT. In this case a metal shield can be placed between the EUT and the antenna. If the signal does not change, it is an ambient signal.

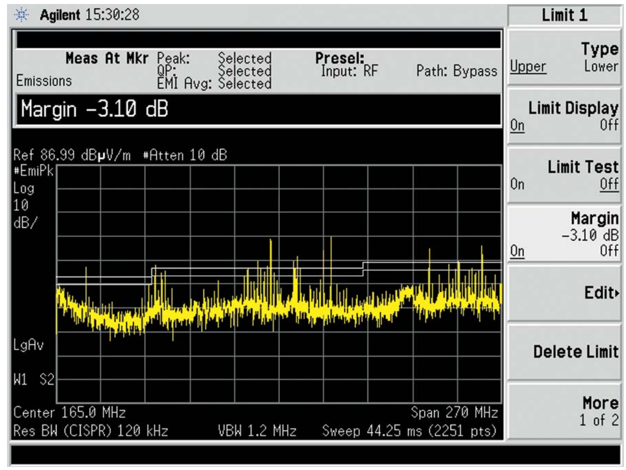


Figure 16. Ambient + EUT emissions.

Appendix A

Line impedance stabilization networks

A1.0 Purpose of a LISN

A line impedance stabilization network serves three purposes:

1. The LISN isolates the power mains from the equipment under test. The power supplied to the EUT must be as clean as possible. Any noise on the line will be coupled to the EMC analyzer and interpreted as noise generated by the EUT.

2. The LISN isolates any noise generated by the EUT from being coupled to the power mains. Excess noise on the power mains can cause interference with the proper operation of other devices on the line.

3. The signals generated by the EUT are coupled to the EMC analyzer using a high pass filter which is part of the LISN. Signals which are in the pass band of the high pass filter see a 50 Ω load which is the input to the EMC analyzer.

A1.1 LISN operation

The diagram in Figure A-1 below shows the circuit for one side of the line relative to earth ground.

Line impedance stabilization network (LISN)

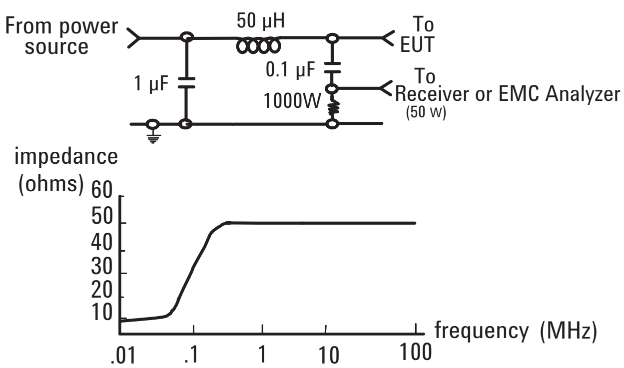


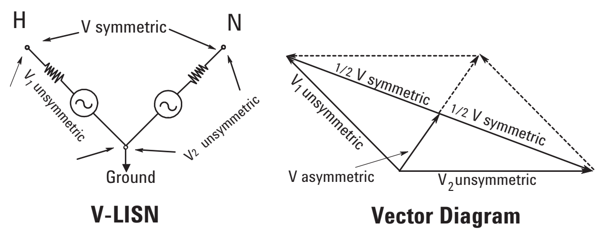
Figure A-1. Typical LISN circuit diagram

The 1 µF capacitor in combination with the 50 µH inductor is the filter that isolates the mains from the EUT. The 50 µH inductor isolates the noise generated by the EUT from the mains. The 0.1 µF capacitor couples the noise generated by the EUT to the EMC analyzer or receiver. At frequencies above 150 kHz, the EUT signals are presented with a 50 Ω impedance.

The chart in Figure A-1 represents the impedance of the EUT port versus frequency.

A1.2 Types of LISNs

Types of LISNs



V-LISN: Unsymmetric emissions (line-to-ground)
△-LISN: Symmetric emissions (line-to-line)
T-LISN: Asymmetric emissions (mid point line-to-line)

Figure A-2. Three different types of LISNs

The most common type of LISN is the V-LISN. It measures the asymmetric voltage between line and ground. This is done for both the hot and the neutral lines or for a three-phase circuit in a "Y" configuration, between each line and ground. There are some other specialized types of LISNs. A delta LISN measures the line to line or symmetric emissions voltage. The T-LISN, sometimes used for telecommunications equipment, measures the asymmetrical voltage, which is the potential difference between the midpoint potential between two lines and ground.

A2.0 Transient limiter operation

The purpose of the limiter is to protect the input of the EMC analyzer from large transients when connected to a LISN. Switching EUT power on or off can cause large spikes generated in the LISN.

The Agilent 11947A transient limiter incorporates a limiter, high pass filter, and an attenuator. It can withstand 10 kW for 10 µsec and has a frequency range of 9 kHz to 200 MHz. The high pass filter reduces the line frequencies coupled to the EMC analyzer.

Appendix B

Antenna factors

B1.0 Field strength units

Radiated EMI emissions measurements measure the electric field. The field strength is calibrated in dBμV/m. Field strength in dBμV/m is derived from the following:

P_t = total power radiated from an isotropic radiator

P_D = the power density at a distance **r** from the isotropic radiator (far field)

$P_D = P_t / 4\pi \mathbf{r}^2$ $\qquad$ $\mathbf{R} = 120\pi\Omega$

$P_D = E^2/\mathbf{R}$

$E^2/R = P_t / 4\pi \mathbf{r}^2$

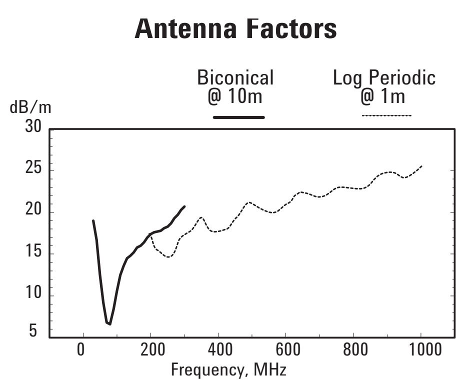
$E = (P_t \times 30)^{1/2} / \mathbf{r}$ (V/m)

Far field* is considered to be $>\lambda s/2\pi$

* Far field is the minimum distance from a radiator where the field becomes a planar wave.

B1.1 Antenna factors

The definition of antenna factors is the ratio of the electric field in volts per meter present at the plane of the antenna versus the voltage out of the antenna connector. Note: Antenna factors are not the same as antenna gain.



Linear Units: AF = Antenna Factor (1/m)
E = Electric Field Strength (V/m)
V = Voltage Output from Antenna (V)

$AF = \frac{Ein}{V\ out}$

Log Units: AF(dB/m) = E(dBμV/m) - V(dBμV)
E(dBμV/m) = V(dBμV) + AF(dB/m)

Figure B-1. Typical antenna factor shapes

B1.2 Types of antennas used for commercial radiated measurements

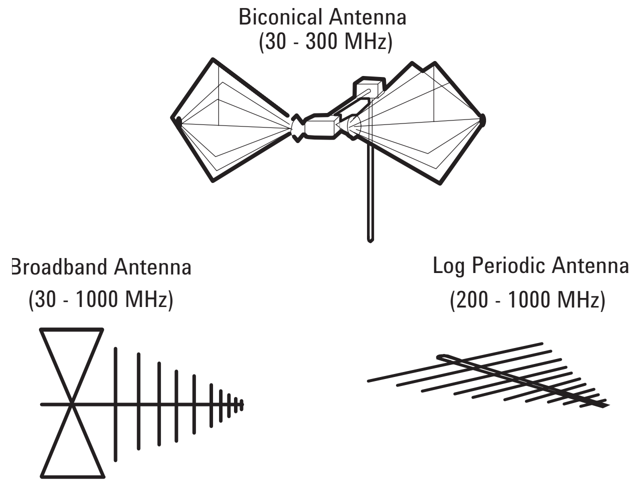


Figure B-2. Antennas used in EMI emissions measurements

There are three types of antennas used for commercial radiated emissions measurements.

Biconical antenna:	30 MHz to 300 MHz
Log periodic antenna:	200 MHz to 1 GHz (The biconical and log periodic overlap frequency)
Broadband antenna:	30 MHz to 1 GHz (Larger format than the biconical or log periodic antennas)

Appendix C

Basic electrical relationships

The decibel is used extensively in electromagnetic measurements. It is the log of the ratio of two amplitudes. The amplitudes are in power, voltage, amps, electric field units, and magnetic field units.

$$\text{decibel} = \text{dB} = 10 \log (P_2/P_1)$$

Data is sometimes expressed in volts or field strength units.

In this case, replace P with V^2/R.

If the impedances are equal, the equation becomes:

$$\text{dB} = 20 \log(V_2/V_1)$$

A unit of measure used in EMI measurements is dBµV or dBµA. The relationship of dBµV and dBm is as follows:

$$\text{dB}\mu\text{V} = 107 + P_{dBm}$$

This is true for an impedance of 50 Ω.

Wave length (l) is determined using the following relationship:

$$\lambda = 3\text{x}10^8 \,/\, f\ (\text{Hz}) \quad \text{or } \lambda = 300/f\ (\text{MHz})$$

Appendix D

Detectors used in EMI measurements-peak, quasi-peak, and average

D1.0 Peak detector

Initial EMI measurements are made using the peak detector.

This mode is much faster than quasi-peak, or average modes of detection. Signals are normally displayed on spectrum analyzers or EMC analyzers in peak mode. Since signals measured in peak detection mode always have amplitude values equal to or higher than quasi-peak or average detection modes, it is a very easy process to take a sweep and compare the results to a limit line. If all signals fall below the limit, then the product passes and no further testing is needed.

D1.2 Peak detector operation

The EMC analyzer has an envelope or peak detector in the IF chain which has a time constant such that the voltage at the detector output follows the peak value of the IF signal at all times. In other words, the detector can follow the fastest possible changes in the envelope of the IF signal, but not the instantaneous value of the IF sine wave (see Figure D-1).

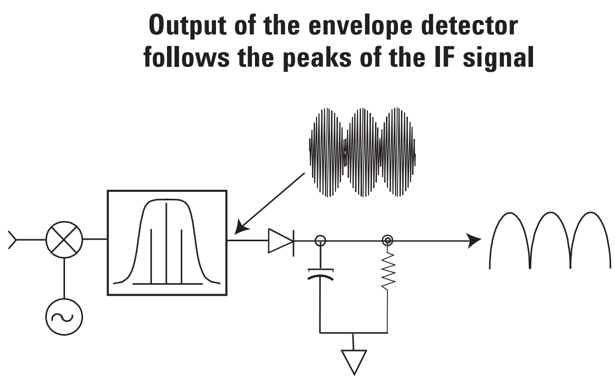


Figure D-1. Peak detector diagram

D2.0 Quasi-peak detector

Most radiated and conducted limits are based on quasi-peak detection mode. Quasi-peak detectors weigh signals according to their repetition rate, which is a way of measuring their annoyance factor. As the repetition rate increases, the quasi-peak detector does not have time to discharge as much resulting in a higher voltage output. (See Figure D-2 below.) For continuous wave (CW) signals the peak and the quasi-peak are the same.

Since the quasi-peak detector always gives a reading less than or equal to peak detection, why not use quasi-peak detection all the time? Won't that make it easier to pass EMI tests? Its true that you can pass the tests easier, however, quasi-peak measurements are much slower by 2 or 3 orders of magnitude compared to using the peak detector.

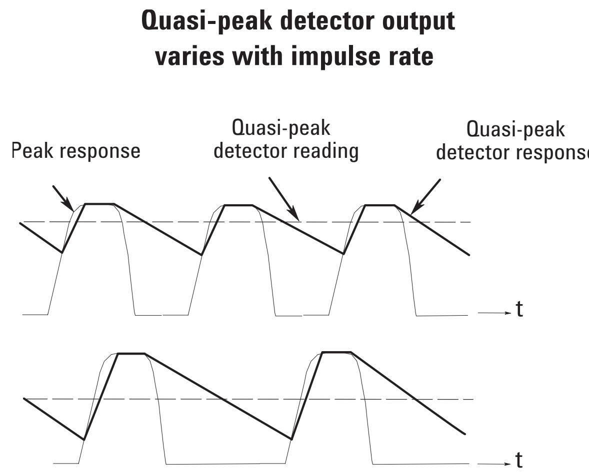


Figure D-2. Quasi-peak detector response diagram

D2.1 Quasi-peak detector operation

The quasi-peak detector has a charge rate much faster than the discharge rate; therefore the higher the repetition rate of the signal the higher the output of the quasi-peak detector. The quasi-peak detector also responds to different amplitude signals in a linear fashion. High amplitude low repetition rate signals could produce the same output as low amplitude high repetition rate signals.

D3.0 Average detector

The average detector is required for some conducted emissions tests in conjunction with using the quasi-peak detector. Also, radiated emissions measurements above 1 GHz are performed using average detection. The average detector output is always less than or equal to peak detection.

D3.1 Average detector operation

Average detection is similar in many respects to peak detection. Figure D-3 below shows a signal that has just passed through the IF and is about to be detected. The output of the envelope detector is the modulation envelope. Peak detection occurs when the post detection bandwidth is wider than the resolution bandwidth. For average detection to take place, the peak detected signal must pass through a filter whose bandwidth is much less than the resolution bandwidth. The filter averages the higher frequency components, such as noise, at the output of the envelope detector.

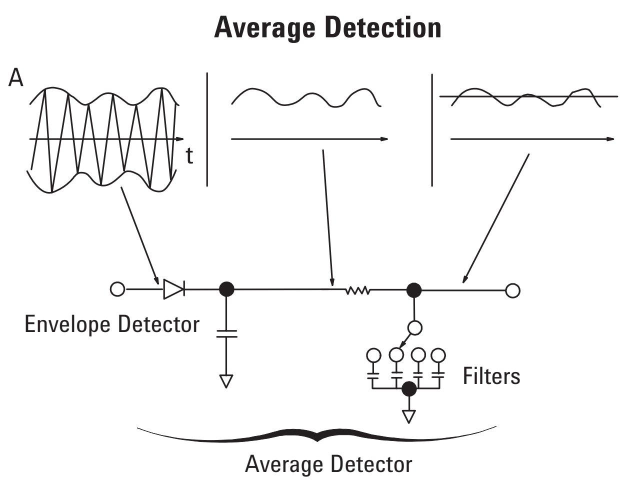


Figure D-3. Average detection response diagram

Appendix E

EMC regulatory agencies

The following is a listing of address and phone numbers for obtaining EMC regulation information.

IEC
CISPR
Sales Department of the Central Office of the IEC
PO Box 131
3, Rue de Verembe
1121 Geneva 20, Switzerland
IEC www.iec.ch
CISPR http://www.iec.ch/zone/emc/emc_cis.htm#guide

ITU-R (CCIR)
ITU, General Secretariat, Sales Service
Place de Nation
1211 Geneva, Switzerland
Telephone: +41 22 730 5111 (ITU Switchboard)
Fax: +41 22 733 7256
http://www.itu.int/ITU-R

Australia
Australia Electromechanical Committee
Standards Association of Australia
PO Box 458
North Sydney N.S.W. 2060
Telephone: +61 2 963 41 11
Fax: +61 2 963 3896
AustraliaElecto-technical Committee
http://www.ihs.com.au/standards/iec/

Belgium
Comite Electrotechnique Belge
Boulevard A. Reyerslaan, 80
B-1030 BRUSSELS
Telephone: Int +32 2 706 85 70
Fax: Int +32 2 706 85 80
http://www.bec-ceb.be

Canada
Standards Council of Canada
Standards Sales Division
270 Albert Street, Suite 200
Ottawa, Ontario K1P 6N7
Telephone: 613 238 3222
Fax: 613 569 7808
http://www.scc.ca

Canadians Standards Association (CSA)
5060 Spectrum Way
Mississauga, Ontario
L4W 5N6
CANADA
Telephone: 416 747 4000
800 463 6727
Fax: 416 747 2473
http://www.csa.ca

Denmark
Dansk Elektroteknisk Komite
Strandgade 36 st
DK-1401 Kobenhavn K
Telephone: +45 72 24 59 00
Fax: +45 72 24 59 02
http://www.en.ds.dk

France
Comite Electrotechnique Francais
UTE CEdex 64
F-92052 Paris la Defense
Telephone: +33 1 49 07 62 00
Fax: +33 1 47 78 71 98
http://www.ute-fr.com/FR

Germany
VDE VERLAG GmbH
Bismarckstr. 33
10625 Berlin
Telephone: + 49 30 34 80 01 - 0 (switchboard)
Fax: + 49 30 341 70 93
email: vertrieb@vde-verlag.de

India
Bureau of Indian Standards, Sales Department
Manak Bhavan
9 Bahadur Shah Zafar Marg.
New Delhi 110002
Telephone: + 91 11 331 01 31
Fax: + 91 11 331 40 62
http://www.bis.org.in

Italy
CEI-Comitato Elettrotecnico Italiano
Sede di Milano
Via Saccardo, 9
20134 Milano
Telephone: 02 21006.226
Fax: 02 21006.222
http://www.ceiweb.it

Japan
Japanese Standards Association
1-24 Akasaka 4
Minato-Ku
Tokyo 107
Telephone: + 81 3 583 8001
Fax: + 81 3 580 14 18
http://www.jsa.or.jp/default_english.asp

Netherlands
Nederlands Normalisatie-Instituut
Afd. Verdoop en Informatie
Kalfjeslaan 2, PO Box 5059
2600 GB Delft
NL
Telephone: (015) 2 690 390
Fax: (015) 2 690 190
www.nni.nl

Norway
Norsk Elektroteknisk Komite
Harbizalleen 2A
Postboks 280 Skoyen
N-0212 Oslo 2
Telephone: 67 83 87 00
Fax: 67 83 87 01
http://www.standard.no/imaker.exe?id=4170

South Africa
South African Bureau of Standards
Electronic Engineering Department
Private Bag X191
Pretoria
0001 Republic of South Africa
https://www.sabs.co.za/Sectors/Electrotechnical/index.aspx

Spain
Comite Nacional Espanol de la CEI
Francisco Gervas 3
E-28020 Madrid
Telephone: + 34 91 432 60 00
Fax: + 34 91 310 45 96
http://www.aenor.es

Sweden
Svenska Elektriska Kommissionen
PO Box 1284
S-164 28 Kista-Stockholm
Telephone: 08 444 14 00
Fax: 08 444 14 30
http://www.elstandard.se/standarder/emc_standarder.asp

Switzerland
Swiss Electrotechnical Committee
Swiss Electromechanical Association
Luppmenstrasse 1
CH-8320 Fehraltorf
Telephone: + 41 44 956 11 11
Fax: + 41 44 956 11 22
http://www. electrosuisse.ch/

United Kingdom
BSI Standards
389 Chiswick High Road
London
W4 4AL
United Kingdom
Telephone: +44 (0)20 8996 9001
Fax: +44 (0)20 8996 7001
www.bsi-global.com

British Defence Standards
DStan Helpdesk
UKDefence Standardization
Room 1138
Kentigern House
65 Brown Street
Glasgow
G2 8EX
Telephone: +44 (0) 141 224 2531
Fax: +44 (0) 141 224 2503
http://www.dstan.mod.uk

United States of America
America National Standards Institute Inc.
Sales Dept.
1430 Broadway
New York, NY 10018
Telephone: 212 642 4900
Fax: 212 302 1286
http://webstore.ansi.org/ansidocstore/default.asp

FCC Rules and Regulations
Technical Standards Branch
2025 M Street N.W.
MS 1300 B4
Washington DC 20554
Telephone: 202 653 6288
http://www.fcc.gov

FCC Equipment Authorization Branch
7435 Oakland Mills Road
MS 1300-B2
Columbia, MD 21046
Telephone: 301 725 1585
http://www.fcc.gov

Glossary of acronyms and definitions

Ambient level
1. The values of radiated and conducted signal and noise existing at a specified test location and time when the test sample is not activated.
2. Those levels of radiated and conducted signal and noise existing at a specified test location and time when the test sample is inoperative. Atmospherics, interference from other sources, and circuit noise, or other interference generated within the measuring set compose the ambient level.

Amplitude modulation
1. In a signal transmission system, the process, or the result of the process, where the amplitude of one electrical quantity is varied in accordance with some selected characteristic of a second quantity, which need not be electrical in nature.
2. The process by which the amplitude of a carrier wave is varied following a specified law.

Anechoic chamber
1. A shielded room which is lined with radio absorbing material to reduce reflections from all internal surfaces. Fully lined anechoic chambers have such material on all internal surfaces: wall ceiling and floor. Its also called a "fully anechoic chamber." A semi-anechoic chamber is a shielded room which has absorbing material on all surfaces except the floor.

Antenna (aerial)
1. A means for radiated or receiving radio waves.
2. A transducer which either emits radio frequency power into space from a signal source or intercepts an arriving electromagnetic field, converting it into an electrical signal.

Antenna factor
The factor which, when properly applied to the voltage at the input terminals of the measuring instrument, yields the electric field strength in volts per meter and a magnetic field strength in amperes per meter.

Antenna induced voltage
The voltage which is measured or calculated to exist across the open circuited antenna terminals.

Antenna terminal conducted interference
Any undesired voltage or current generated within a receiver, transmitter, or their associated equipment appearing at the antenna terminals.

Auxiliary equipment
Equipment not under test that is nevertheless indispensable for setting up all the functions and assessing the correct performance of the EUT during its exposure to the disturbance.

Balun
A balun is an antenna balancing device, which facilitates use of coaxial feeds with symmetrical antennae such as a dipole.

Broadband emission
Broadband is the definition for an interference amplitude when several spectral lines are within the RFI receivers specified bandwidth.

Broadband interference (measurements)
A disturbance that has a spectral energy distribution sufficiently brad, so that the response of the measuring receiver in use does not vary significantly when tuned over a specified number of receiver bandwidths.

Conducted interference
Interference resulting from conducted radio noise or unwanted signals entering a transducer (receiver) by direct coupling.

Cross coupling
The coupling of a signal from one channel, circuit, or conductor to another, where it becomes an undesired signal.

Decoupling network
A decoupling network is an electrical circuit for preventing test-signals which are applied to the EUT from affecting other devices, equipment, or systems that are not under test. IEC 801-6 states that the coupling and decoupling network systems can be integrated in one box or they can be in separate networks.

Dipole

1. An antenna consisting of a straight conductor usually not more than a half-wavelength long, divided at its electrical center for connection to a transmission line.
2. Any one of a class of antennas producing a radiation pattern approximating that of an elementary electric dipole.

Electromagnetic compatibility (EMC)

1. The capability of electronic equipment of systems to be operated within a defined margins in of safety in the intended operational environment at designed levels of efficiency without degradation due to interference.
2. EMC is the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances into that environment or into other equipment.

Electromagnetic interference

Electromagnetic interference is the impairment of a wanted electromagnetic signal by an electromagnetic disturbance.

Electromagnetic wave

The radiant energy produced by the oscillation of an electric charge characterized by oscillation of the electric and magnetic fields.

Emission

Electromagnetic energy propagated from a source by radiation or conduction.

Far field

The region where the power flux density from an antenna approximately obeys an inverse squares law of the distance. For a dipole this corresponds to distances greater than l/2 where l is the wave length of the radiation.

Ground plane

1. A conducting surface of plate used as a common reference point for circuit returns and electric or signal potentials.
2. A metal sheet or plate used as a common reference point for circuit returns and electrical or signal potentials.

Immunity

1. The property of a receiver or any other equipment or system enabling it to reject a radio disturbance.
2. The ability of electronic equipment to withstand radiated electromagnetic fields without producing undesirable responses.

Intermodulation

Mixing of two or more signals in a nonlinear element, producing signals at frequencies equal to the sums and differences of integral multiples of the original signals.

Isotropic

Isotropic means having properties of equal values in all directions.

Monopole

An antenna consisting of a straight conductor, usually not more than one-quarter wave length long, mounted immediately above, and normal to, a ground plane. It is connected to a transmissions line at its base and behaves, with its image, like a dipole.

Narrowband emission

That which has its principal spectral energy lying within the bandpass of the measuring receiver in use.

Open area

A site for radiated electromagnetic interference measurements which is open flat terrain at a distance far enough away from buildings, electric lines, fences, trees, underground cables, and pipe lines so that effects due to such are negligible. This site should have a sufficiently low level of ambient interference to permit testing to the required limits.

Polarization

A term used to describe the orientation of the field vector of a radiated field.

Radiated interference

Radio interference resulting from radiated noise of unwanted signals. Compare radio frequency interference below.

Radiation
The emission of energy in the form of electromagnetic waves.

Radio frequency interference
RFI is the high frequency interference with radio reception. This occurs when undesired electromagnetic oscillations find entrance to the high frequency input of a receiver or antenna system.

RFI sources
Sources are equipment and systems as well as their components which can cause RFI.

Shielded enclosure
A screened or solid metal housing designed expressly for the purpose of isolating the internal from the external electromagnetic environment. The purpose is to prevent outside ambient electromagnetic fields from causing performance degradation and to prevent emissions from causing interference to outside activities.

Stripline
Parallel plate transmission line to generate an electromagnetic field for testing purposes.

Susceptibility
Susceptibility is the characteristic of electronic equipment that permits undesirable responses when subjected to electromagnetic energy.

Remove all doubt

Our repair and calibration services will get your equipment back to you, performing like new, when promised. You will get full value out of your Agilent equipment throughout its lifetime. Your equipment will be serviced by Agilent-trained technicians using the latest factory calibration procedures, automated repair diagnostics and genuine parts. You will always have the utmost confidence in your measurements.

Agilent offers a wide range of additional expert test and measurement services for your equipment, including initial start-up assistance onsite education and training, as well as design, system integration, and project management.

For more information on repair and calibration services, go to:

www.agilent.com/find/removealldoubt

Agilent Email Updates

www.agilent.com/find/emailupdates
Get the latest information on the products and applications you select.

Agilent Direct

www.agilent.com/find/agilentdirect
Quickly choose and use your test equipment solutions with confidence.

Agilent Open

www.agilent.com/find/open
Agilent Open simplifies the process of connecting and programming **test systems** to help engineers design, validate and manufacture electronic products. Agilent offers open connectivity for a broad range of system-ready instruments, open industry software, PC-standard I/O and global support, which are combined to more easily integrate test system development.

LXI

www.lxistandard.org
LXI is the LAN-based successor to GPIB, providing faster, more efficient connectivity. Agilent is a founding member of the LXI consortium.

www.agilent.com

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

www.agilent.com/find/contactus

Americas	
Canada	(877) 894-4414
Latin America	305 269 7500
United States	(800) 829-4444

Asia Pacific	
Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	81 426 56 7832
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Thailand	1 800 226 008

Europe	
Austria	0820 87 44 11
Belgium	32 (0) 2 404 93 40
Denmark	45 70 13 15 15
Finland	358 (0) 10 855 2100
France	0825 010 700
Germany	01805 24 6333* *0.14€/minute
Ireland	1890 924 204
Italy	39 02 92 60 8 484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
Switzerland (French)	41 (21) 8113811(Option 2)
Switzerland (German)	0800 80 53 53 (Option 1)
United Kingdom	44 (0) 118 9276201

Other European Countries:
www.agilent.com/find/contactus

Revised: May 7, 2007

Product specifications and descriptions in this document subject to change without notice.

Printed in USA, August 15, 2007
5989-6899EN

Agilent Technologies