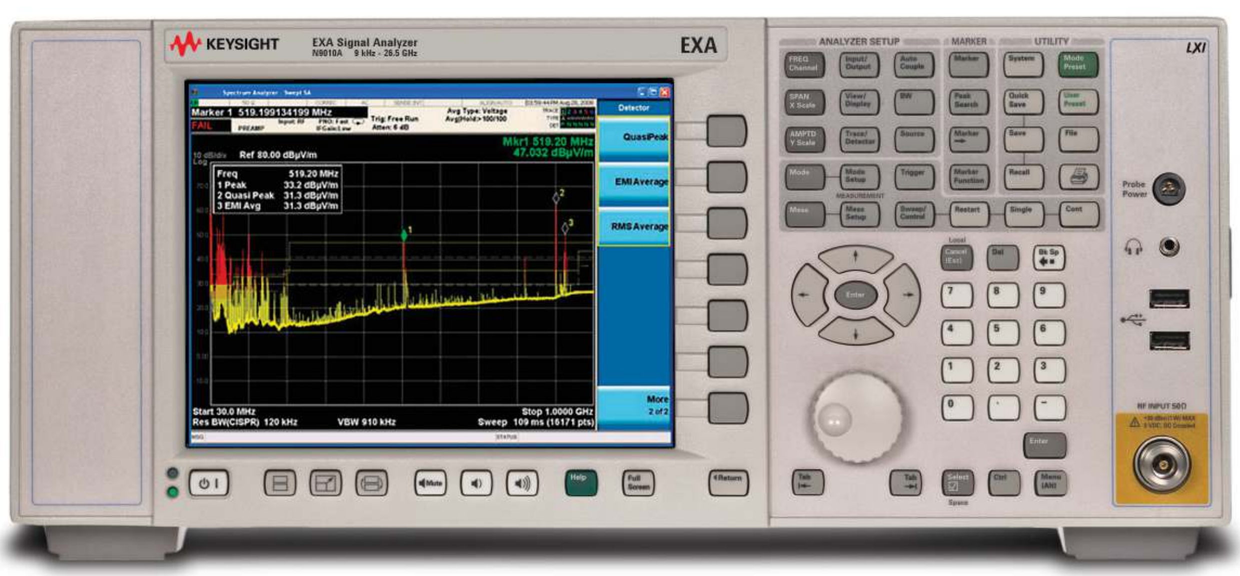
# Keysight Technologies

## Making Precompliance Conducted and Radiated Emissions Measurements with Option EMC for the X-Series Signal Analyzers (CXA/EXA/MXA/PXA)

Application Note




KEYSIGHT
TECHNOLOGIES

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# 1.0 Introduction to Precompliance Measurements

The concept of getting a product to market on time and within budget is nothing new. However, companies have added some new steps to the introduction process to achieve those goals. One of those steps in the process is the addition of an EMC (electro-magnetic compatibility) strategy. Manufacturers have realized that in order to sell their electronic products on the commercial market, they must pass EMC requirements. Waiting until the end of the development cycle to find out whether or not a product passes regulatory agency requirements can be an expensive gamble. Failing to pass can result in costly redesign. Because of this, developers are concerned about the EMC performance of a new product from design investigation through preproduction units. Figure 1 below shows a typical product development cycle.

Many manufacturers use EMI precompliance measurement systems to perform conducted and radiated EMI emissions tests prior to sending their product to a test facility for full compliance testing. Conducted emissions testing focuses on signals, present on the AC mains, that are generated by the EUT (equipment under test). The test range for these measurements is from 9 kHz to 30 MHz, depending on the regulation.

Radiated emissions testing looks for signals broadcasted from the EUT through space. The frequency range for these measurements is between 30 MHz and 1 GHz, depending on the regulation. Testing to higher frequencies may be required depending on the device and the internal clock frequency. This preliminary testing is called precompliance testing. Figure 2 illustrates the relationship 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. In order to experience an electromagnetic compatibility problem, such as when an electric drill interferes with TV reception, there must be a generator or source, a coupling path, and a receptor. An EMC problem can be eliminated by removing one of the components: generator, coupling path, or receptor.

Until recently, most of the concentration has been to reduce the generator emissions to remove an EMC problem (that is, reduce the emissions from the source to an acceptable level).

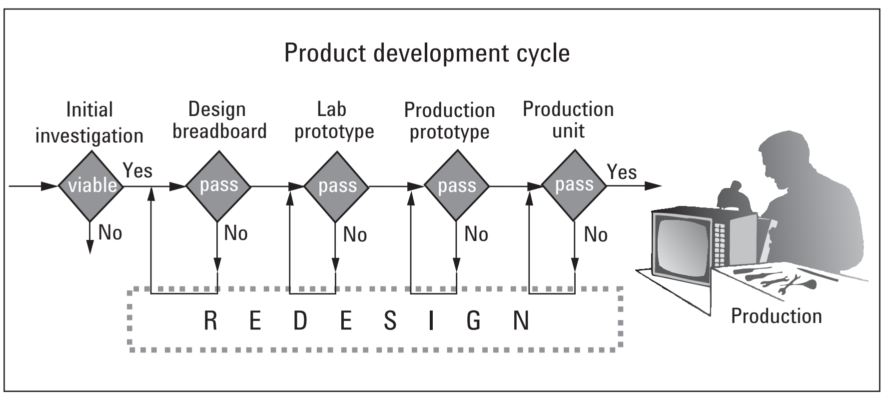


*Figure 1. A typical product development cycle*

With the advent of the European requirements, there is additional focus on product immunity. The level of electrical field that a receptor can withstand before failure is known as the product immunity. The term immunity and susceptibility are used interchangeably. Immunity testing will not be covered in this document.

## 1.1 Precompliance measurements versus full compliance measurements

Full compliance measurements require the use of a receiver that meets the requirements set forth in the CISPR[1] part 16-1-1 document, a qualified open area test site or chamber, and an antenna tower and turntable to maximize the signals from the EUT.

Great effort is taken to get the best accuracy and repeatability. This can be very expensive. The photograph below shows a full compliance test facility.

Precompliance measurements are intended to give an approximation of the EMI performance of the EUT. The cost of performing precompliance tests is a fraction of full compliance measurements. The more attention to detail, such as a good ground plane and minimizing the number of reflective objects in the measurement area, the better the accuracy of the measurements.

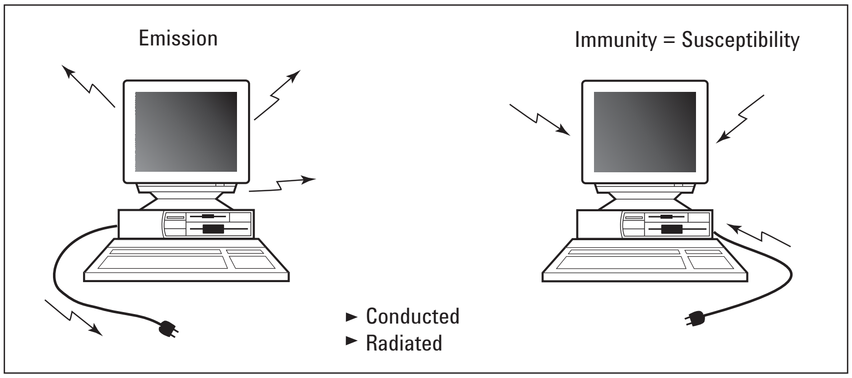


*Figure 2. Electromagnetic compatibility between products*

*Anechoic chamber (Courtesy of TDK Corporation)*

1. Comite International Special des Perturbations Radioelectriques

# 2.0 EMI Precompliance Systems

The components of a precompliance test system include an EMC analyzer, a line impedance stabilization network (LISN), antennas, close field probes, and interconnection cables (Figure 3). The test environment for precompliance testing is usually less controlled than full compliance testing, which is performed on an open area test site (OATS) or a chamber.

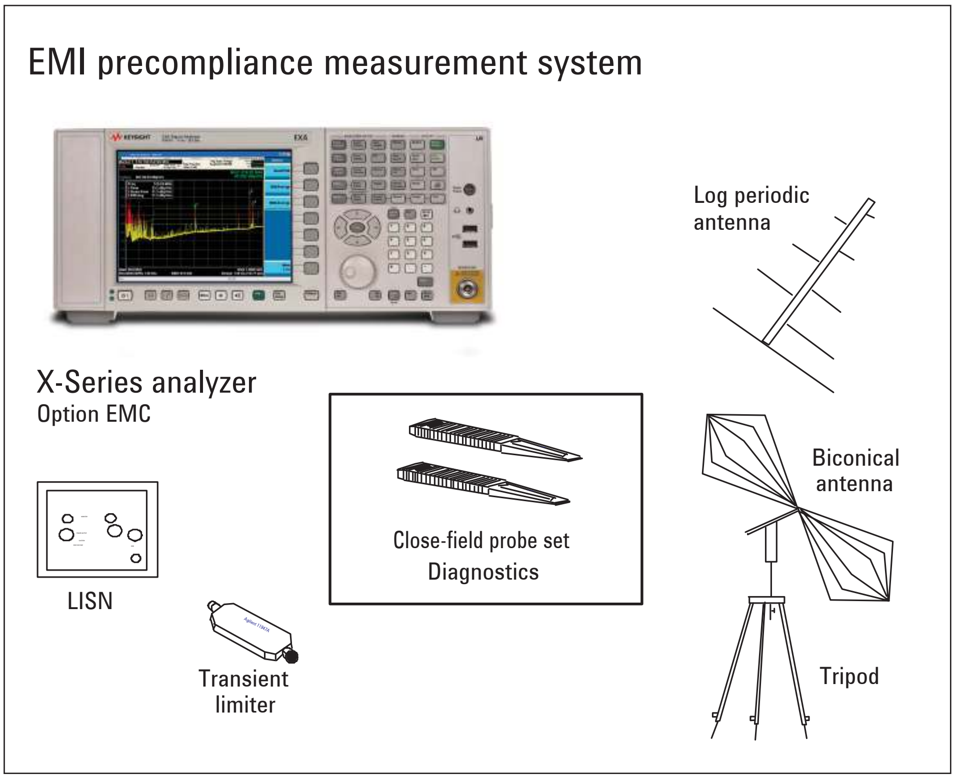


*Figure 3. Components of a preproduction evaluation system*

# 3.0 Precompliance Measurements Process

The precompliance measurement process is fairly straightforward. However, before measurements can be performed on a product, some preliminary questions must be answered.

1. Where is the product to be sold (in other words, United States, Europe, Japan, etc.)?
2. What is the classification of the product (that is, information technology equipment [ITE] devices; industrial, scientific, medical [ISM] devices; automotive or communications)?
3. Where is the product to be used (i.e., home, commercial, light industry, or heavy industry)?

With the answers to these questions, you can then determine which requirements your product must be tested to. For example, if you have determined that your product is an ITE device and you are going to sell it in the United States, then you need to test the product to the FCC part 15 regulation. See Tables 1a and 1b to choose the requirement for your product. When in doubt, call the appropriate agency for final conformation with the applicable requirement. (A list of phone numbers is included in Appendix E.)

## Emissions regulations (summary)

| FCC | CISPR | EN's | Description |
|---|---|---|---|
| 18 | 11 | EN 55011 | Industrial, scientific and medical |
| — | 12 | — | Automotive |
| 15 | 13 | EN 55013 | Broadcast receivers |
| | 14 | EN 55014 | Household appliances/tools |
| | 15 | EN 55015 | Fluorescent lights/luminaries |
| 15 | 22 | EN 55022 | Information technology equipment |
| | — | EN 50081 | Generic emissions standards |
| | 16 | — | Measurement apparatus/methods |
| | 16 | EN 55025 | Automotive component test |

*Table 1a. Comparison of regulatory agency requirements*

## European norms detail description

### 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, microwave therapy equipment.)

## EN55014 (CISPR 14)

Electric motor-operated and thermal appliances for household and similar purposes, electric tools, and electric apparatus.

Household and similar appliances
(conducted)

Household and similar appliances
(radiated)
Motors < 700 W (conducted)
Motors < 700 W (radiated)
Motors <1000 W (conducted)
Motors <1000 W (radiated)
Motors >1000 W (conducted)
Motors >1000 W (radiated)

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, telecommunications equipment.)

Class A ITE: Not intended for domestic use.

Class B ITE: Intended for domestic use.

### Federal Communications Commission

| Equipment Type | FCC |
|---|---|
| • Broadcast receivers | Part 15 |
| • Household appliances | Class A Industrial |
| • Fluorescent lights/luminaries | Class B Residential |
| • Information technology/equipment (ITE) | |
| • Industrial, scientific, and medical (ISM) | Part 18 |
| • Conducted measurements: 450 kHz - 30 MHz | |
| • Radiated measurements: 30 MHz - 1000 MHz, 40 GHz | |

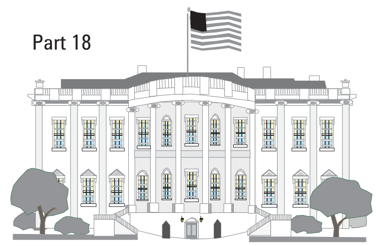

*Table 1b. FCC requirements summary*

## Federal Communications Commission Equipment Detailed Description FCC Part 15

## Radio frequency devices—Unintentional radiators

For example, TV broadcast receivers, FM broadcast receivers, CB receivers, scanning receivers, TV interface devices, cable system terminal devices, 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:

Marketed for use in a commercial, industrial, or business environment.

## Class B digital devices:

Marketed for use in a residential environment.

# 4.0 Emissions Testing

## 4.1 Introduction

After the appropriate regulations have been identified, the next step is to set up the test equipment and perform conducted and radiated emissions tests. The first group of tests to perform is conducted emissions tests. The process we will follow will be to interconnect the equipment, load in the appropriate limit line from the X-Series' internal memory, correct for LISN (line impedance stabilization network) and transient limiter (see Appendix A) and perform the tests.

Note: Keystrokes surrounded by { } indicate hard keys located on the front panel, while key names surrounded by [ ] indicate soft keys located on the right edge of the display.

The X-Series should be in DC coupled mode. Press {Input}, [RF input], [RF coupling DC].

## 4.2 Conducted emissions measurements

Emissions testing are divided into conducted emissions and radiated emissions testing. Conducted emissions testing are the easiest to perform. Follow these steps to set up the equipment and the EUT (equipment under test).

1. Interconnect the EMC analyzer, limiter, LISN, and EUT as shown in Figure 4. (Operation of the LISN and transient limiter is cover in Appendix A.)

2. Power up the X-Series

3. From {Mode Preset}, Press {mode setup}, [EMC Std], [CISPR], [CISPR Presets] and [CISPR B]. The X-Series Option EMC is now in band B with the correct bandwidth (9 kHz CISPR BW), and the correct span (150 kHz to 30 MHz). The detector is EMI peak.

Conducted emissions measurements are easier than ever!

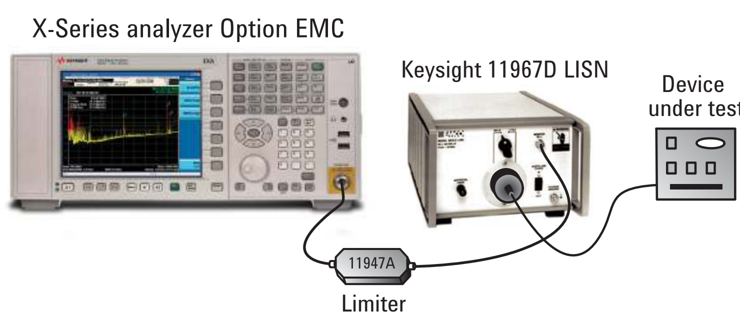


*Figure 4. Conducted measurements interconnection*

4. Select and load the limit line from the internal file of the X-Series based on the type of equipment and the regulatory agency requirements. Select and load the limit line using the following steps.

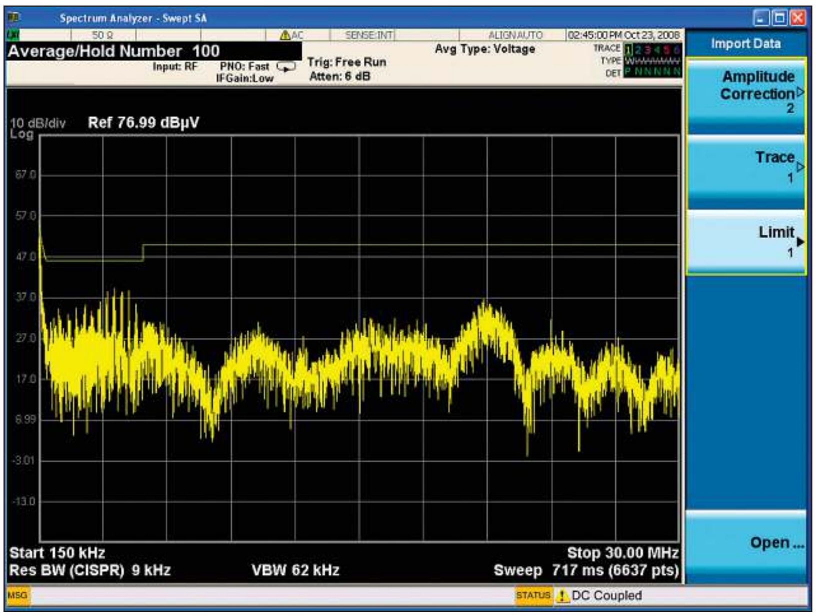


*Figure 5. Regulatory limits displayed*

Press {Recall}, [Data], [Limit], [Limit 1] and [Open]. The “My documents” folder will appear on the display. Scroll to “EMC Limits and ampcor” and open. Select limits, change file type to .Lim, and scroll to the required limit line, in this case EN55022 class B Conducted Quasi-Peak and click on open (see Figure 5). Set a margin by pressing {Meas Setup}, [Limits], [Margin On] and enter a value (6 dB for example).

5. If the limit test indicator is not on you can switch it on by pressing {Meas Setup}, [Limit], [More],

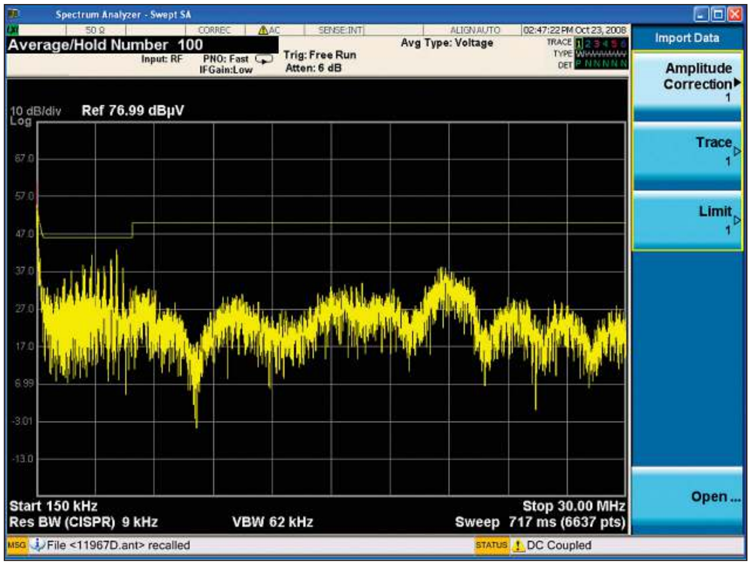


*Figure 6. Display corrected for LISN factors*

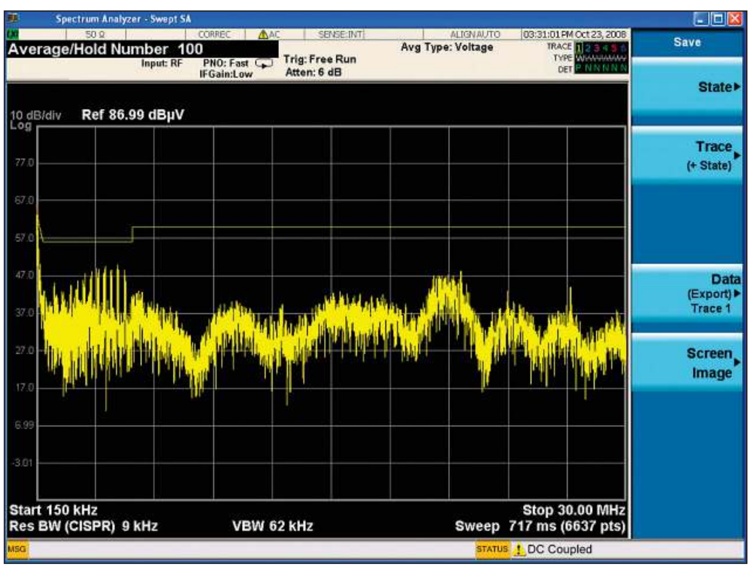


*Figure 7. Display corrected for limiter losses*

[Test Limits On].

6. Correct for the LISN press {Recall}, [Data], [Correction], [Correction 1] and [Open]. The "My documents" folder will appear on the display. Scroll to "EMC Limits and ampcor" and [open]. Select Ampcor, select file type .ant, then scroll to the 11967D or LISN 10 Amps and press [Open].

7. The correction factors loaded in step 6 are generic in that they are typical factors for a LISN. If you have the correction factors for your LISN, you can adjust the factors that you have loaded. Press {Input}, [More], [Corrections]. Select the correction factor number you wish to adjust by pressing [Select Correction] then the correction number. Press [Edit] and a table of amplitude frequency pair will appear. Navigate to the amp/freq pair by pressing [Navigate], and use the up/down arrows to your destination. Use the [Frequency] and [Amplitude] keys to change the values. Note that the trace changes as you change the values .

8. Correct for the transient limiter press {Recall}, [Data], [Correction], [Correction 2] and [Open]. The "My documents" folder will appear on the display. Scroll to "EMC Limits and ampcor" and [Open]. Scroll to the 11947A transient limiter and press [Open].

## 4.3 Performing conducted emissions measurements

At this point the X-Series Option EMC signal analyzer is set up with all the correct parameters, including bandwidth, frequency range, LISN and limiter compensation, and limit line with margin.

There is one more thing to consider before starting conducted measurements -- 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 power of the EUT off and check the display to ensure that the noise floor and ambient signals are at least 6 dB below the limit line (see Figure 8).

If signals appear above the limit, the interconnecting power cord may need to be shortened or a shield added around the cord. Do not use a ferrite core on the power cord because common mode signals coming from the EUT can also be attenuated giving false indications.

## 4.4 Starting the conducted measurements process

Turn on the EUT and observe the display. If no signals appear above the limit line, the product passes the conducted emissions limit and your job is done. Most of the time, testers are not so lucky. There are usually signals above the limit that need closer analysis. Conducted emissions usually occur in the lower end of the band.

### 4.4.1 Overload test

Before starting the measurements, test to ensure that the X-Series signal analyzer is not in overload. An overload condition occurs when the energy level at the input mixer is very high, causing errors in amplitude measurements. To test for this condition do the following: Press {Amplitude}, [Attenuation], [Mech Atten], and up arrow which increases the attenuation before the input mixer. If the signal does not change amplitude on the display, the mixer is not overloaded. If the amplitude of the signal does increase then the input is overloaded and more attenuation is required until the signal does not change amplitude with additional attenuation.

### 4.4.2 Signal measurements

The next step is to perform a quasi-peak measurement on signals above

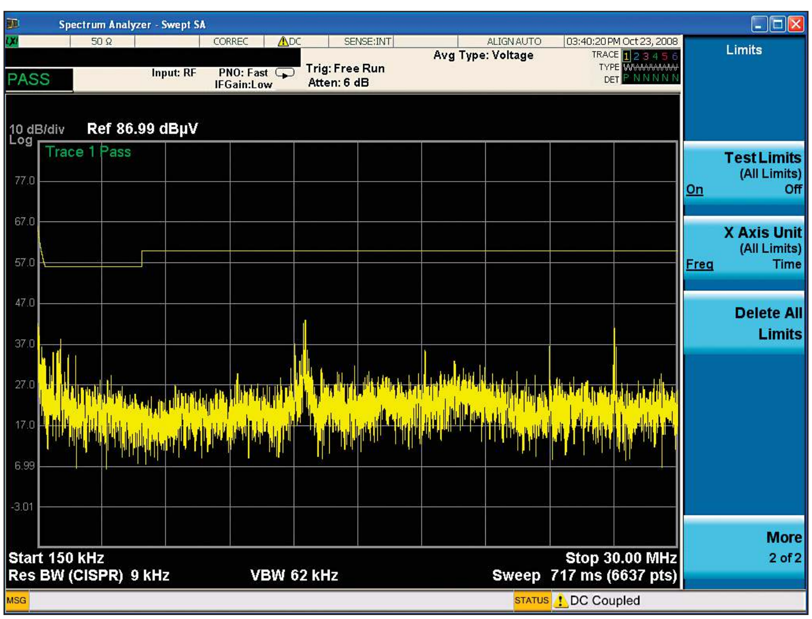


*Figure 8. Noise picked up by power cord with EUT off*

the limit line. One method is to use the "Measure at Marker" function. But before we get started, it is recommended that the trigger be changed from free run to line by pressing {Trigger} and [Line]. This will help to stabilize the display.

at Marker] and [Measure at Marker] again. Record the frequency/amplitude values. Repeat the process for each of the signals above the limit.

Compare the measurement results to the limit line values. Probably one of the best ways to do this is to place the frequency/amplitude values in a spread sheet along with the limit line values. If the QP values are higher than the limit line value for a specific frequency then some redesign will be required.

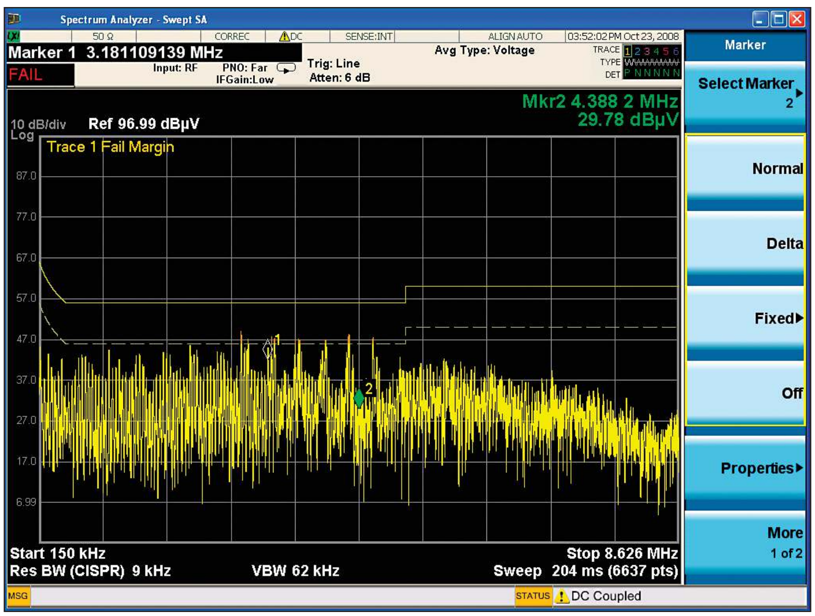


*Figure 9. Conducted emissions from EUT*

## 4.5 Radiated emissions measurements preparation

Performing radiated emissions measurements is not as straightforward as performing conducted EMI measurements. There is the added complexity of the ambient environment which could interfere with the emissions from the EUT. There are methods to differentiate between ambient environment signals (TV, FM, cellular, etc.) and EUT signals.

1. Arrange the antenna, EUT and X-Series signal analyzer as shown in Figure 10. Separate the antenna and the EUT by 3 meters. (Use 10 meters if it is called out in the regulation. If space is limited correct the results for the difference in distance between 3 meter and 10 meters which is 10.45 dB.)
   It is important that the antenna not be placed within the near field region which is λ/2π away from the EUT or closer. The X-Series has a 20 dB amplifier built-in. For increased gain, use the Keysight Technologies, Inc. 11909A amplifier with 32 dB gain and with 1.8 dB noise figure.
2. Set up the X-Series Option EMC with the correct span, antenna correction factors, and limit line with a margin. To set the correct span, bandwidth and detector, press {mode setup}, [EMC std], [CISPR], [CISPR presets], and [CISPR C]. To load the limit line (in this case the EN55022 Class A Radiated 10 meter) press {Recall}, [Data], [Limit], [limit 1], [Open], scroll to EMC Limits and ampcor, select file type .Lim, select Limits, then [Open], scroll to EN55022 Class A Radiated 10 meter and open. Add a margin by pressing {Meas Setup}, [Limits], [Margin On], {6}, [dB]. Next select the correction factors for the biconical antenna 11955A. Press {Recall}, [Data], [Amplitude Correction], [Correction 1], [Open] file type .ant. Scroll to 11955A biconical antenna and [Open]. Typical correction factors for a biconical antenna are now loaded. See Figure 11 for a typical display of radiated measurements.

### 4.5.1 Editing and saving corrections

The antenna correction factors that are supplied with the Option EMC software are typical values for various types of antennas including biconical, log periodic and broad band. You can edit these values by pressing [Input], {more}, {Corrections} and {Edit}. Use the {Navigate} and the up/down keys to select a frequency/amplitude pair. Make changes as needed and save. To save the edited correction factors, press [Save], {data}, {Amplitude correction 1}, {Save as}, enter the antenna name and press {Save}.

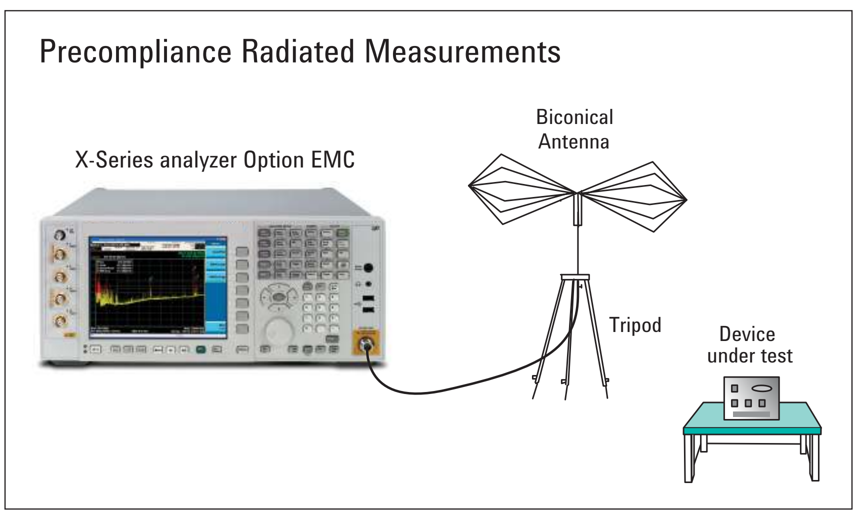


*Figure 10. Radiated emissions test setup*

## 4.6 Measuring radiated emissions

Now you can start evaluating the radiated emissions your product produces. With the EUT off, sweep the frequency range of interest to survey the ambient environment levels. The ideal situation would be to have all the ambient signals below the limit line margin. The next section discusses how to measure signals above a margin or limit.

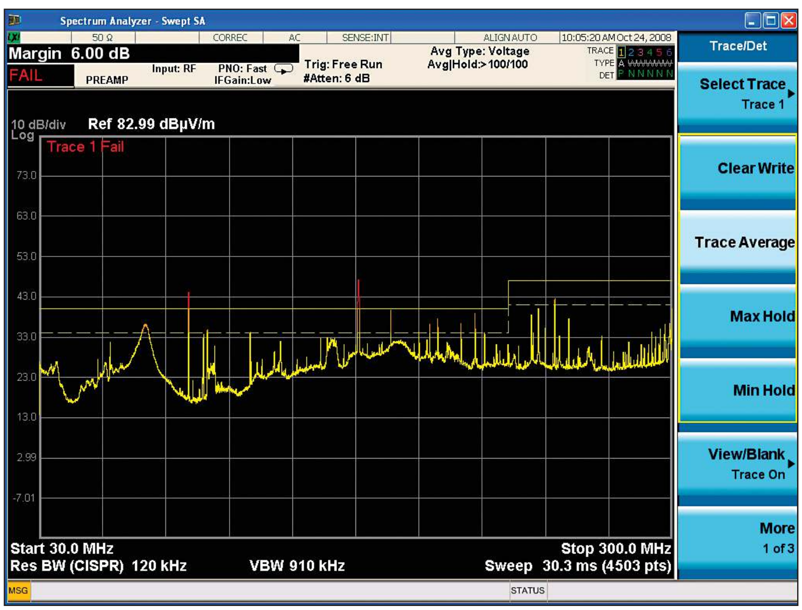


*Figure 11. Display with limit line and correction factors*

## 4.7 Ambient signal measurements

The process for measuring the ambient signals above the limit is as follows:

1. Reduce the span and set the start frequency so that the sweep starts at the beginning of the band. The span should be set so that there are 10 or 15 signals above the limit.
2. Measure and record the frequency and amplitude of each of the signals above the limit.
3. Move the center frequency so that the start frequency is at the previous stop frequency. This can be easily done by setting the center frequency step size equal to the span and use the up/down arrows to move the center frequency.

At this point, you have recorded all the ambient signals (CW or impulsive) above the limit line. You will refer back to this list in making a determination whether or not a signal is a DUT or ambient signal.

## 4.8 Placement of DUT for maximum signals

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

Press {Meas Setup}, [CISPR Presets], [CISPR C]. This selects the 30 to 300 MHz band which matches the frequency range of a biconical antenna.

At each 45 degree step of rotation note the amplitude of the largest signals above the limit. A good way of comparing the emissions is to print each step. If you do not have a printer connected you can capture the screen to the Paint application and save to a file for later comparison. Be sure to identify the position on each screen capture.

After all the screens have been captured, compare them to find the position with the worst case emissions. In some cases, you may find that there are worst case emissions for different frequencies at different positions. For example, 100 MHz emissions may be worst case at 90 degrees and 200 MHz emissions may be worst case at 270 degrees. In this case, the emissions tests must be performed at both positions. A typical screen is shown in Figure 12.

If you are not sure whether the signal you are looking at is an ambient or DUT signal, switch the power off on the EUT. If the signal remains, then it is an ambient signal.

Repeat the above process of positioning the DUT using the other polarization of the antenna (that is, vertical or horizontal).

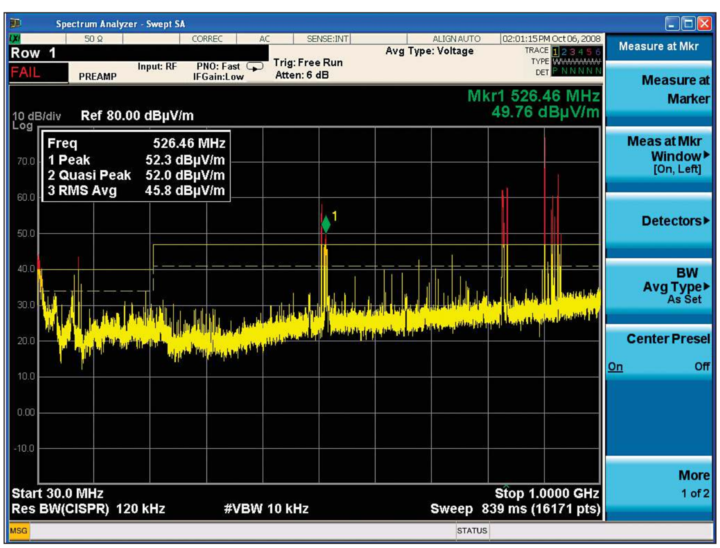


*Figure 12. Radiated emissions display*

## 4.9 Final analysis of the DUT signals

Each one of the worst case emissions must be measured using the quasi-peak detector. Position the DUT so that the worst case emissions are pointed toward the antenna. Using the data entry knob place the marker on each of the signals above the limit. Perform a measure at marker by pressing {Marker Function}, [Measure at Marker], [Measure at Marker]. Record the frequency and QP value. After you have performed these measurements on all the signals above the limit that are not ambient signals, compare the value to the QP limit value at that frequency. If all QP values are below the limit, you pass and no further work is required.

## 4.10 Report development

It is recommended that a report be generated. Place the QP measurements in one column, the associated frequencies in a second column and the limit line value for the frequency in a third column. Subtract the QP value from the limit line value and place in a fourth column. This will give you the margin and a record of previous measurements. You then can compare measurements you make in the future to the previous measurements.

# 5.0 Problem Solving and Troubleshooting

At this point, after the product has been tested and the results are recorded, your product is either ready for full compliance testing and production, or it must go back to the bench for further diagnosis and/or repair.

If the product needs further redesign, the following process is recommended.

1. Connect the diagnostic tools as shown in Figure 13.
2. From the recorded results locate the problem frequencies.
3. Use the probe to locate the source or sources of the problem frequencies.
4. With the probe placed to give the maximum amplitude, save the trace + state to a register.
5. Make circuit changes as necessary to reduce the emissions.
6. Re-measure the circuit using the same settings as in step 4.
7. Recall the previous measurement that had been stored to a register and compare the results to the current measurement.

## 5.1 Diagnostics testing setup

As with emissions testing, the X-Series must be set up to perform diagnostics testing. Corrections for the close field probe and amplifier (if used) must first be loaded into the X-Series Option EMC signal analyzer. The Keysight 11945A close field probe kit contains two probes: the 11941A (9 kHz to 30 MHz) and the 11940A (30 MHz to 1 GHz). Connect the probe for the appropriate frequency range to the input of the X-Series signal analyzers.

[Corrections 1], [Open], file type .ant. Scroll to 11940A and open. If you are using an external preamplifier load in the correction factors by pressing {Recall}, [Data], [Corrections], [Corrections 2], [Open]. Select .amp from the drop down menu and scroll to 11909A amplifier and open. The probe corrections are placed in Correction 1 and the amplifier corrections are placed in Correction 2.

The X-Series signal analyzer is now calibrated in dBμA/m, a magnetic field strength unit.

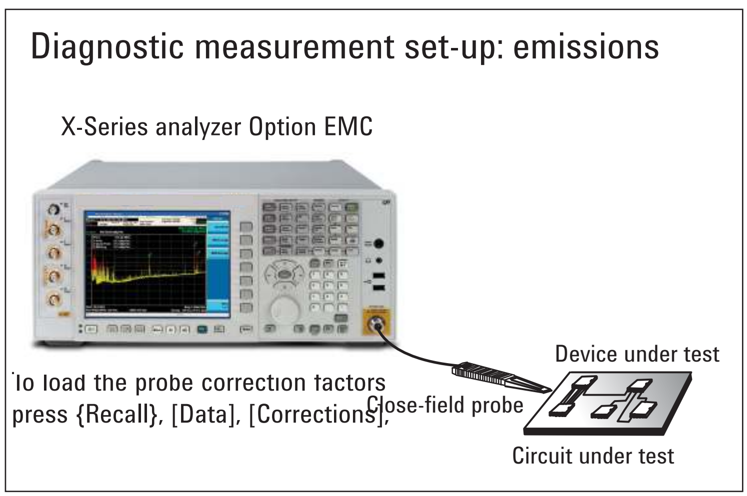


*Figure 13. Diagnostics setup interconnection*

## 5.2 Problem isolation

Using the recorded data for conducted and radiated measurements you recorded earlier, tune the X-Series to one of the problem frequencies with narrow enough span to give adequate differentiation
between signals.

Move the close field probe slowly over the device under test. Observe the display for maximum emissions. After you have isolated the source of the emissions, record the location and save the display to a register. To save the signal to a register, press {Save}, [Trace + State], [Register 1] (see Figure 14).

The next step is to make design changes to reduce the emissions. This can be accomplished by adding or changing circuit components, redesigning the problem circuit, or adding shielding.

After the redesign, re-measure the results comparing the old trace to the new trace you are currently measuring. Press {Recall}, [Trace + State], [To Trace], [Trace 2], [Register 1]. With your probe on the trouble spot, compare the emissions before and after repairing the problem (see Figure 15).

As you can see from the different marker level, there is an improvement of about 10 dB after redesign. There is a one-to-one relationship between changes in close field probe measurements and far field measurements. For example, if you note a 10 dB change in measurements made with a close field probe you will note a 10 dB change when you perform a far field measurement using an antenna and an X-Series signal analyzer.

Conversely, if you find that the radiated emissions from your EUT are failing a limit by 10 dB then you will need some redesigning in order to reduce the emissions by at least 10 dB. A good indication that you have accomplished your goal is to make a 10 dB change with close field measurements.

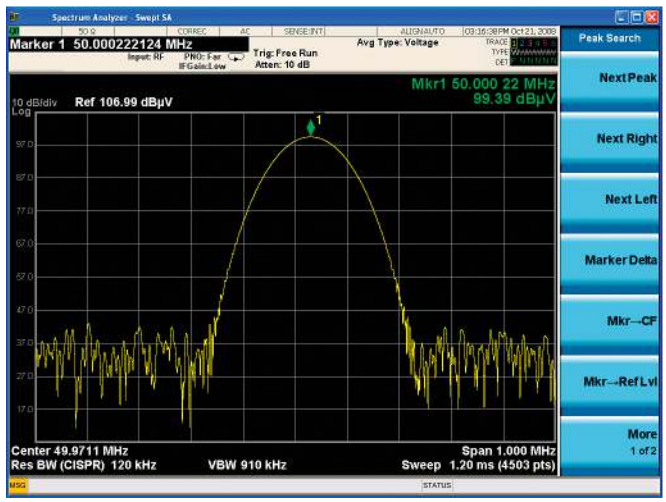


*Figure 14. Isolated signal source display*

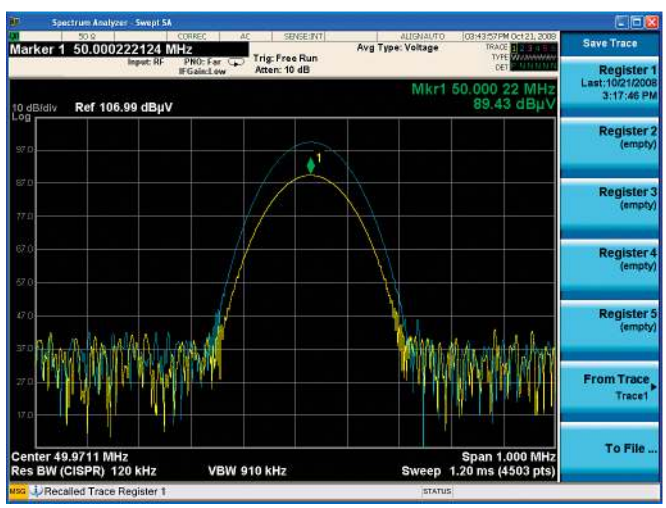


*Figure 15. Emissions reduction comparison display*

# Appendix A: Line Impedance Stabilization Networks (LISN)

## 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 X-Series signal 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 X-Series analyzer using a high-pass filter, which is part of the LISN. Signals that are in the pass band of the high-pass filter see a 50-Ω load, which is the input to the X-Series signal 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.

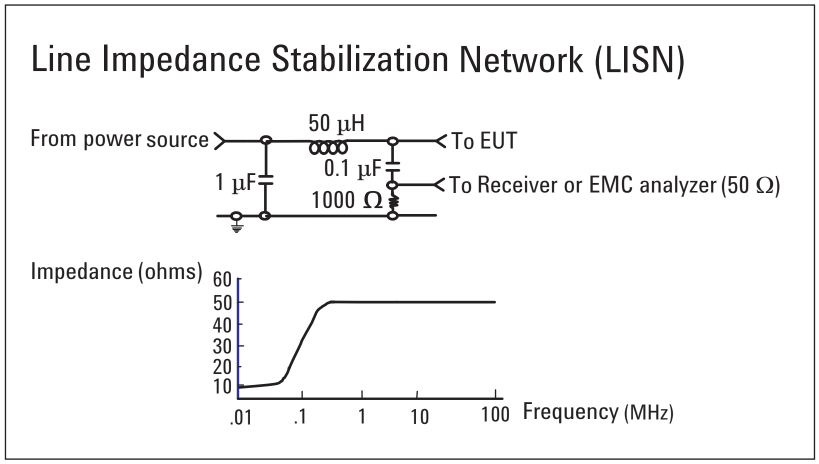


*Figure A-1. Typical LISN circuit diagram*

The 1 µF 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 couples the noise generated by the EUT to the X-Series signal 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

The most common type of LISN is the V-LISN. It measures the unsymmetric 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 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 asymmetric 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 Keysight 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.

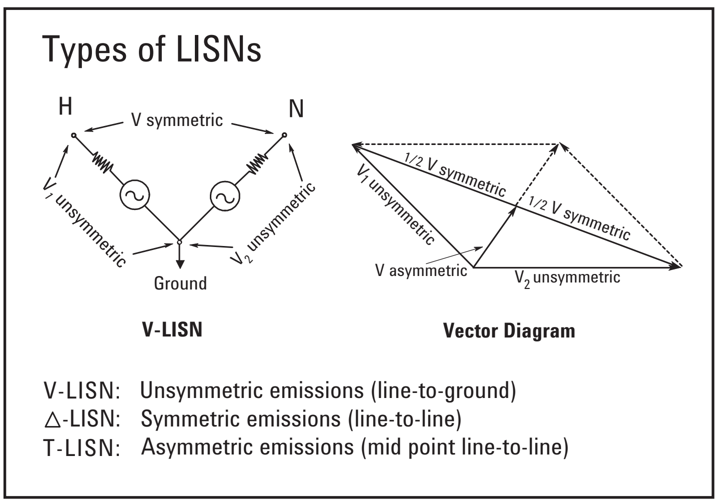


*Figure A-2. Three different types of LISNs*

# 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)

$P_D = P_t / 4\pi r^2$

$R = 120\pi\Omega$

$P_D = E^2/R$

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

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

Far field[1] is considered to be $>\lambda/2\pi$

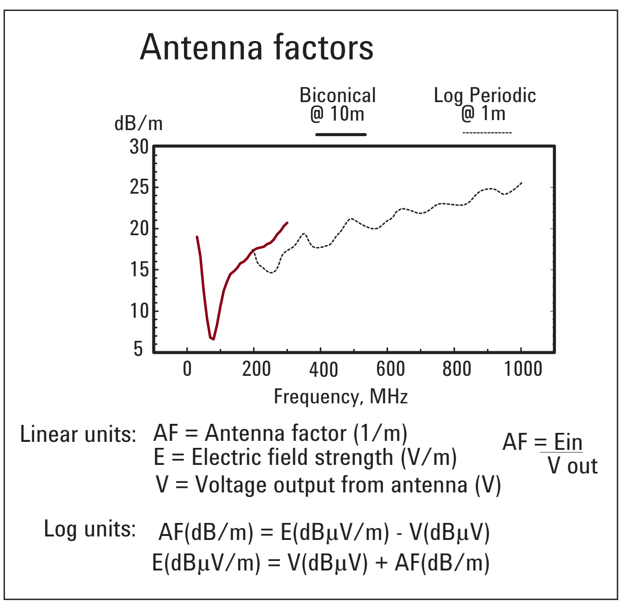


*Figure B-1. Typical antenna factor shapes*

1. 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.

## B1.2 Types of antennas used for commercial radiated 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)

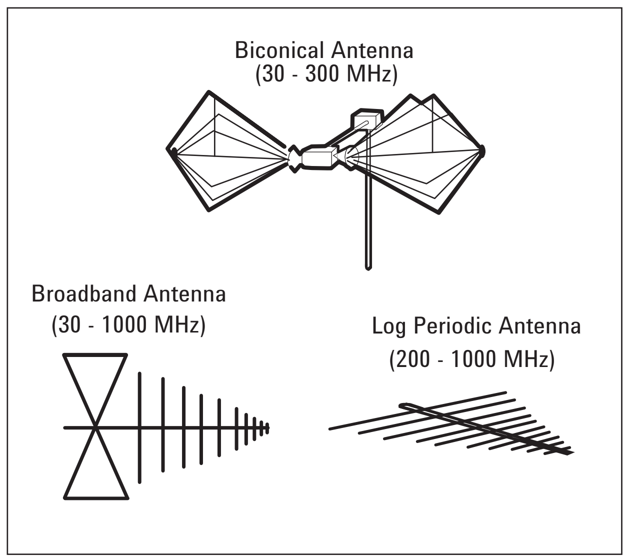


*Figure B-2. Antennas used in EMI emissions measurements*

# 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.

decibel = dB = 10 log $(P_2/P_1)$

Data is sometimes expressed in volts or field strength units. In this case, replace P with V2/R.

If the impedances are equal, the equation becomes:

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:

dBµV = 107 + $P_{dBm}$

This is true for an impedance of 50 Ω.

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

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

# Appendix D: Detectors Used in EMI Measurements

## 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.

## D1.1 Peak detector operation

The EMC analyzer has an envelope or peak detector in the IF chain that 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.)

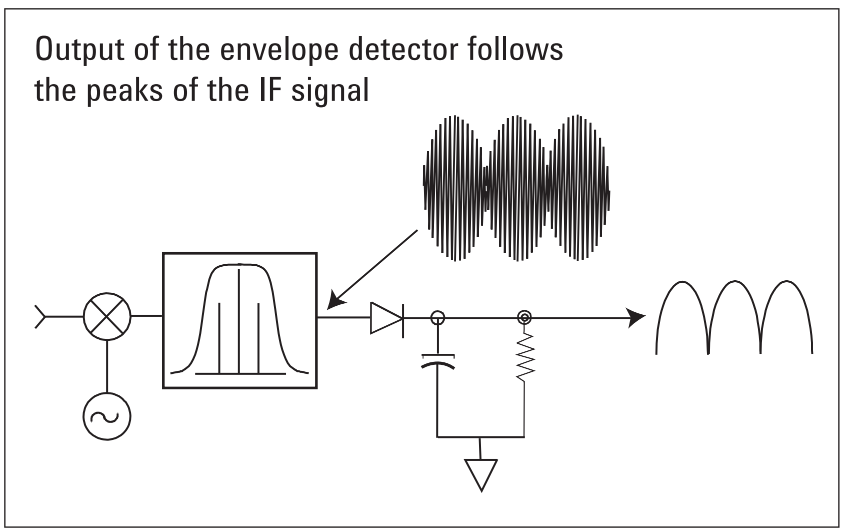


*Figure D-1. Peak detector diagram*

## 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.) 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? It's true that you can pass the tests more easily; however, quasi-peak measurements are much slower by two or three orders of magnitude compared to using the peak detector.

### 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 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.

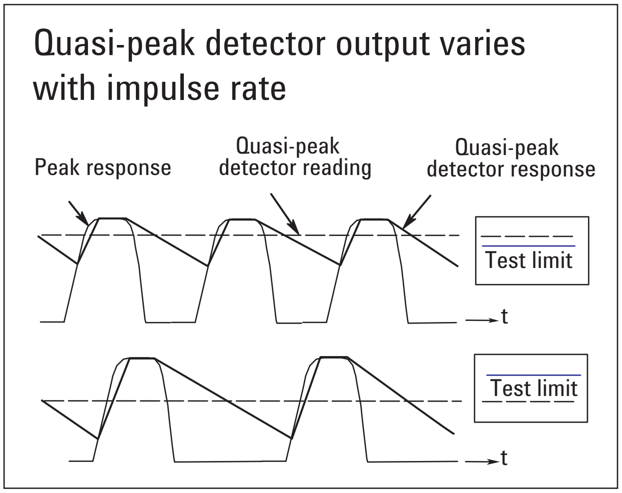


*Figure D-2. Quasi-peak detector response diagram*

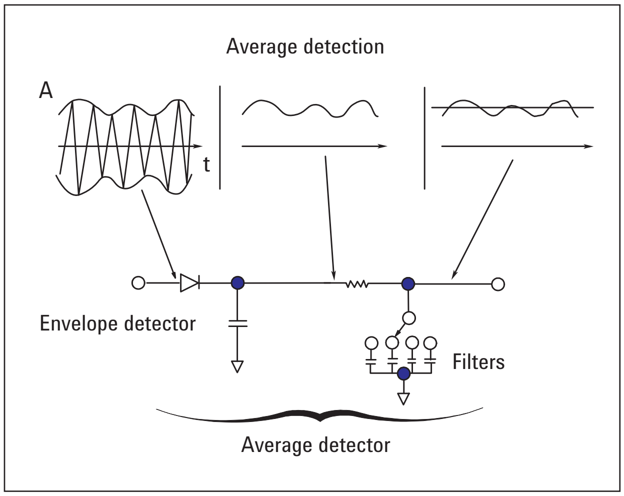


*Figure D-3. Average detection response diagram*

# Appendix E

## EMC regulatory agencies

The following is a list 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 broad, 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 defined margins of safety in the intended operating 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 or 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 transmission 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.

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| Malaysia | 1 800 888 848 |
| Singapore | 1 800 375 8100 |
| Taiwan | 0800 047 866 |
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