

Agilent AN 1328

Making Precompliance Conducted and Radiated Emissions Measurements with EMC Analyzers

Application Note

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Agilent E7400A Series



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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 the 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).

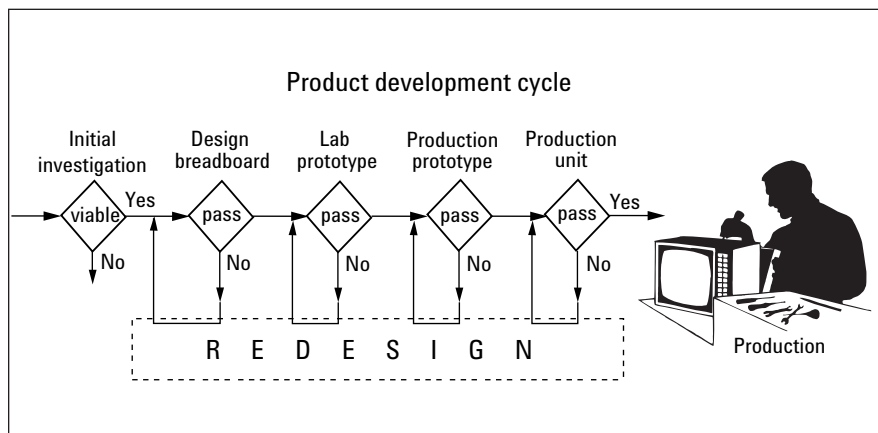


Figure 1. A typical product development cycle

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.

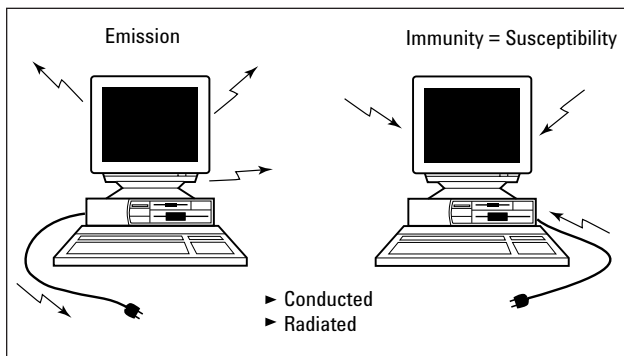


Figure 2. Electromagnetic compatibility between products

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 CISPR¹ part 16 document, a qualified open area test site, 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.



2.0 EMI Precompliance Systems

The components of a precompliance test system (the Agilent Technologies 84115EM preproduction evaluation system, for example) include an EMC analyzer, a line impedance stabilization network (LISN), antennas, close field probes, and intercon-

nection 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).

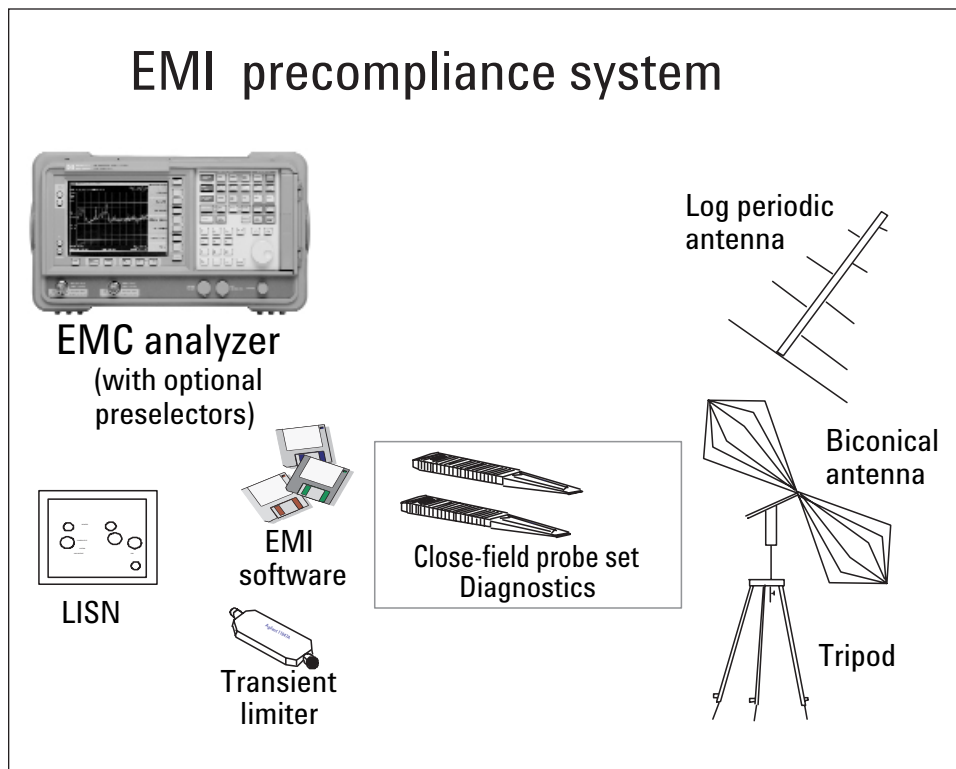


Figure 3. Components of a preproduction evaluation system

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 the above questions, you can then determine to which requirements your product must be tested. 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.)

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.)

Table 1a. Comparison of regulatory agency requirements

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

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 in the table on the following page.

Household and similar appliances (conducted) (Disk file names)
(replace with new file names on all)

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.

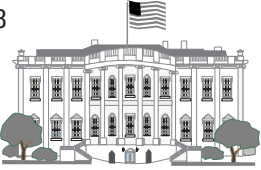
EN55022 (CISPR 22)**Information Technology Equipment**

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.

Table 1b. FCC requirements summary

Federal Communications Commission	
Equipment Type	FCC
<ul style="list-style-type: none">• Broadcast receivers• Household appliances• Fluorescent lights / luminaries• Information technology / equipment (ITE)	Part 15 Class A Industrial Class B Residential
<ul style="list-style-type: none">• Industrial, scientific, and medical (ISM)• Conducted measurements: 450 kHz - 30 MHz• Radiated measurements: 30 MHz - 1000 MHz, 40 GHz	Part 18 

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 radiated and conducted 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 ROM card, correct for the LISN and transient limiter (see Appendix A), and perform the tests.

4.2 Conducted emissions measurements preparation

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

1. Interconnect the EMC analyzer, limiter, LISN, and EUT as shown in Figure 4 (printer is optional).

(Operation of the LISN and the limiter is covered in Appendix A.)

2. Power up the EMC analyzer.
3. Set up the correct frequency range. Press [MEAS SETUP], <150 kHz–30 MHz>.

Note: The disk drive is in path “A.” If the path is in “C” when attempting to load from “A,” use [↓], [↑] to highlight “A.” Then press <Select>.

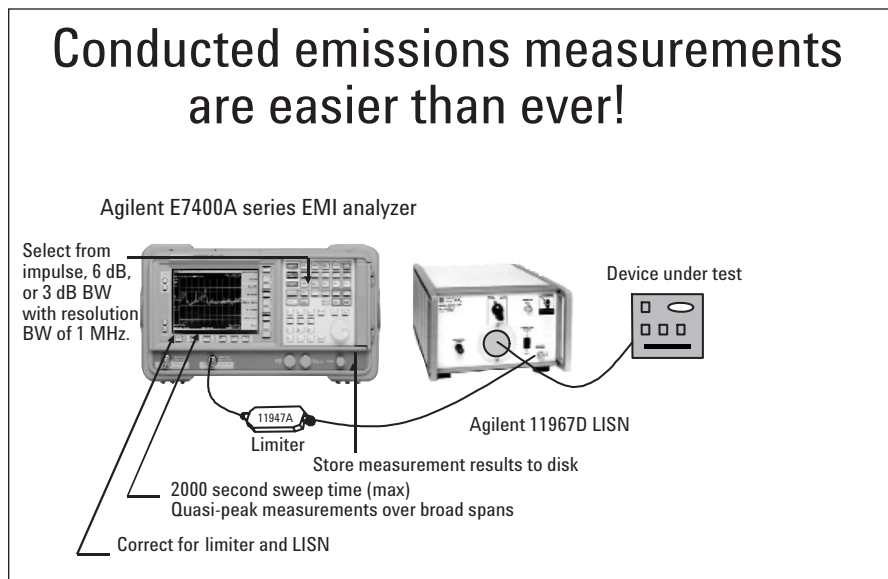


Figure 4. Conducted measurements interconnection

4. Select and load the limit line from the disk supplied, based on the type of equipment and the regulatory agency requirements. Selecting and loading limit lines is accomplished by pressing the following buttons on the EMC analyzer:

[FILE], <Load>, <Limits>, <Limit 1>, scroll down and highlight the required limit line

(in other words, EN22BCQP, which is the conducted limits for Class B products). Press [ENTER]. (See Figures 5a and 5b.)

5. Switch on limit test to indicate whether or not signals pass the requirement. Press [Meas. Setup], <more>, <limits>, <Modify>, <test on>.

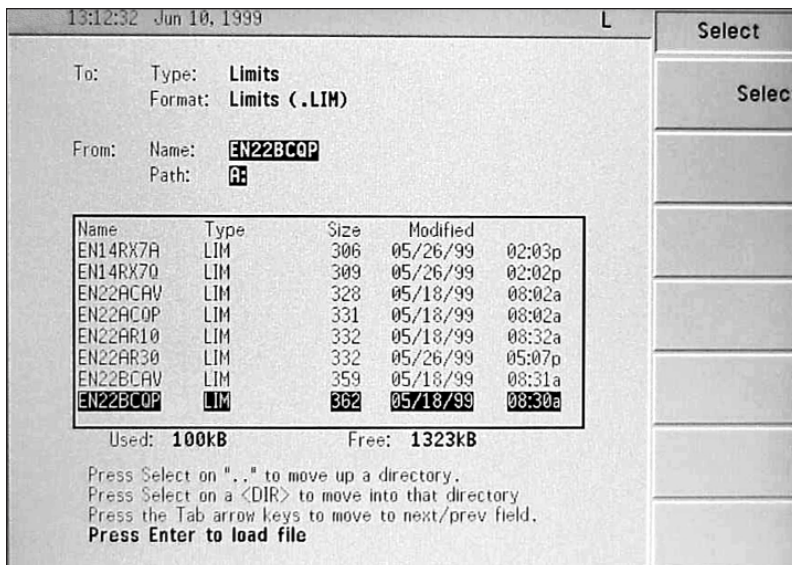


Figure 5a. Partial list of regulatory limits

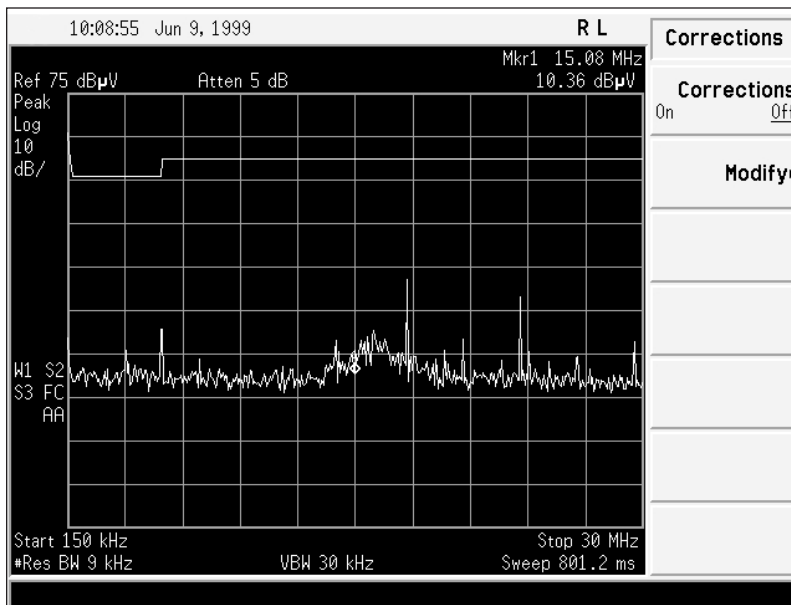


Figure 5b. Regulatory limits displayed

6. Correct for the LISN. The disk contains typical correction factors. To correct the display for the LISN, press the following buttons:

[FILE], <Load>, <Corrections>. Scroll down to the LISN you are using. Press [ENTER].
Agilent offers two LISNs, 11967E (25 amps) and 11967D (10 amps). (See Figures 6a and 6b.)

7. Enable corrections for LISN. Press [MEAS SETUP], <More>, <Corrections>, <Modify>, <Select>, <Antenna>, <Correction on>.

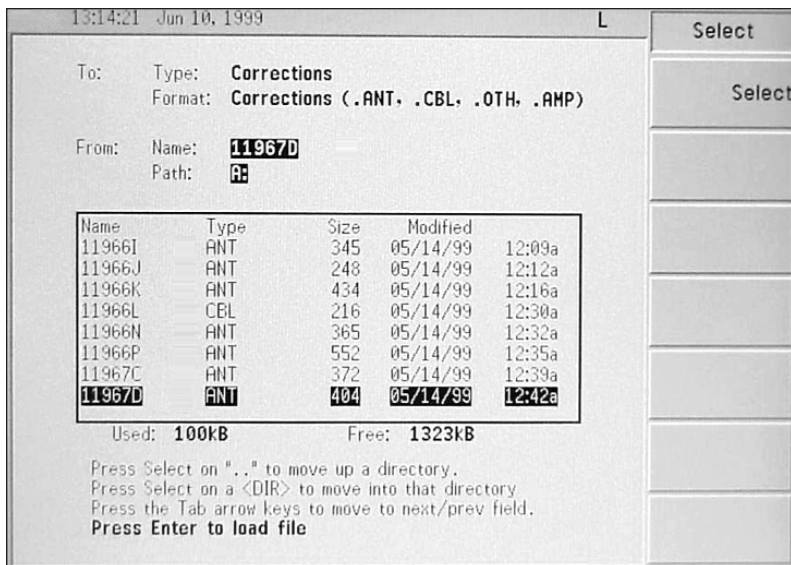


Figure 6a. List of typical transducers

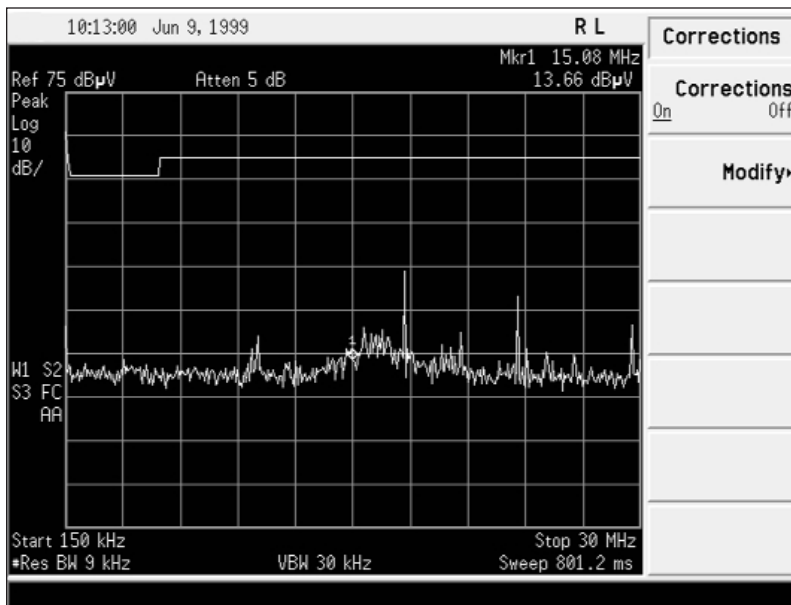


Figure 6b. Display corrected for LISN factors

8. Correct the display for the Agilent 11947A transient limiter by pressing the following buttons:

[FILE], <Load>, <Corrections>, select 11947A and [ENTER]. (See Figures 7a and 7b.)

9. To enable the correction factors for the limiter, press [MEAS SETUP], <More>, <Corrections>, <Modify>, <Select>, <Other>, <Correction on>.

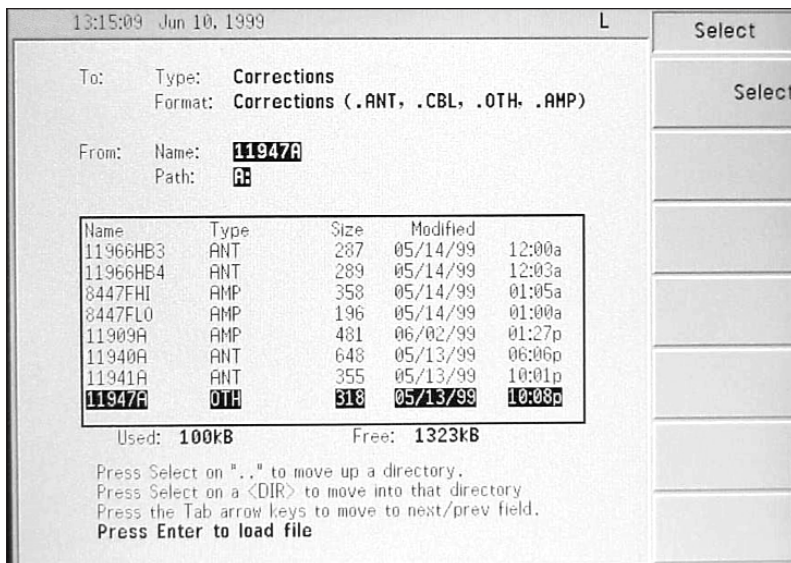


Figure 7a. List including limiter

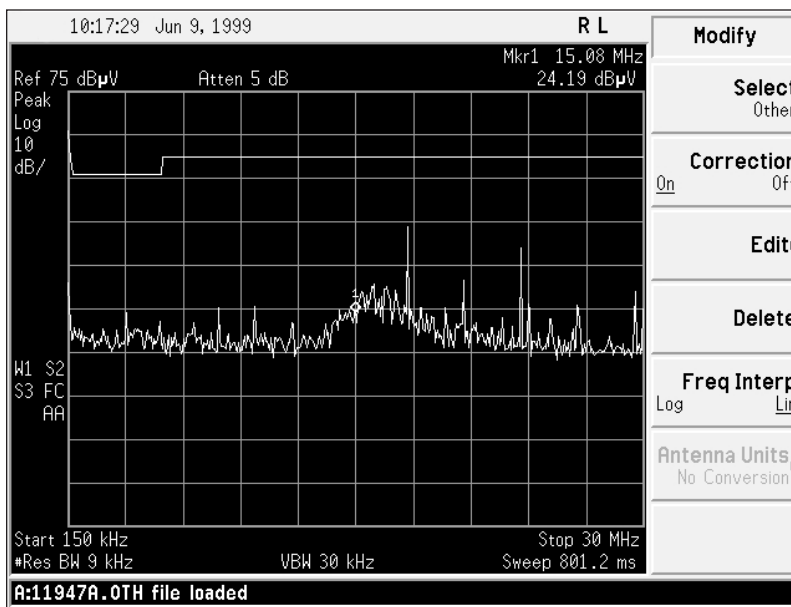


Figure 7b. Display corrected for limiter losses

4.3 Performing conducted emissions measurements

At this point the EMC analyzer is set up with all the correct parameters, including bandwidth, frequency range, LISN and limiter compensation, and limit line. 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 line on the display, the interconnecting power cord may need to be shortened or a shield may be needed around the cord. Do not use a ferrite core around the power cord because the 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 power 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, you should test to ensure that the EMC analyzer is not in overload. An overload condition occurs when the energy level at the input mixer of the EMC analyzer is very high, causing errors in amplitude measurements. To test for this condition, do the following: Press [AMPLITUDE], <Attenuation Man>, <↑>, which increases the attenuation before the input mixer of the EMC analyzer. If the signal does not change position on the display, then the mixer is not overloaded. If the amplitude of the signal does increase, then the input is overloaded and additional attenuation must be added.

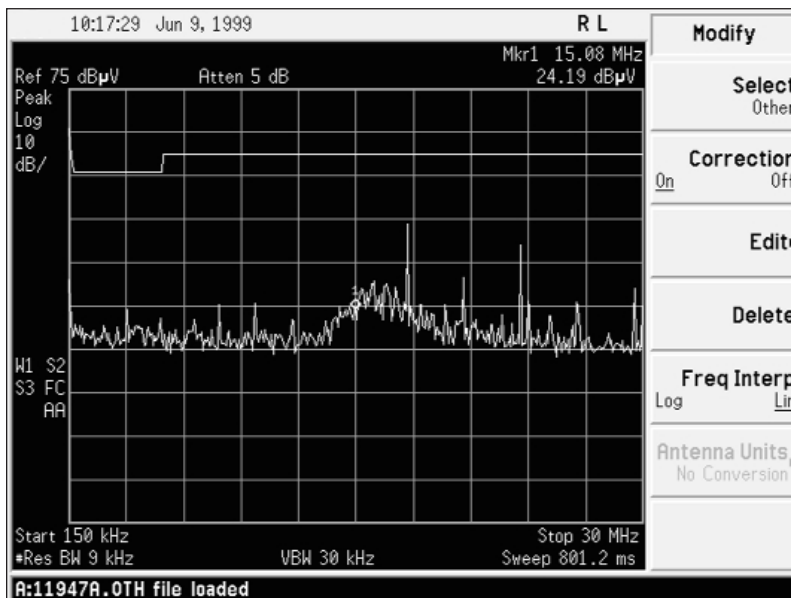


Figure 8. Noise picked up by power cord with EUT off

4.4.2 Signal measurements

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

To measure the peak and quasi-peak level of a signal (see Appendix D), perform the following:

Press [MEAS SETUP], <More>, <Meas Detector>, <Peak on>, <Quasi peak on>. Press [SPAN], <Zone>, <Zone on>; use <ZONE CENTER> and <ZONE SPAN> to show the signals of interest in the active trace. (See Figure 9.)

To measure the peak and quasi-peak level of a signal of interest, press [MEASURE], <Marker normal>, then use the knob or the up/down keys to place the marker on the signal.

Press <Meas at marker>. After the measurement is completed, the signal frequency, peak, and quasi-peak amplitudes will appear in the box above the display. Press <Meas to list>.

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

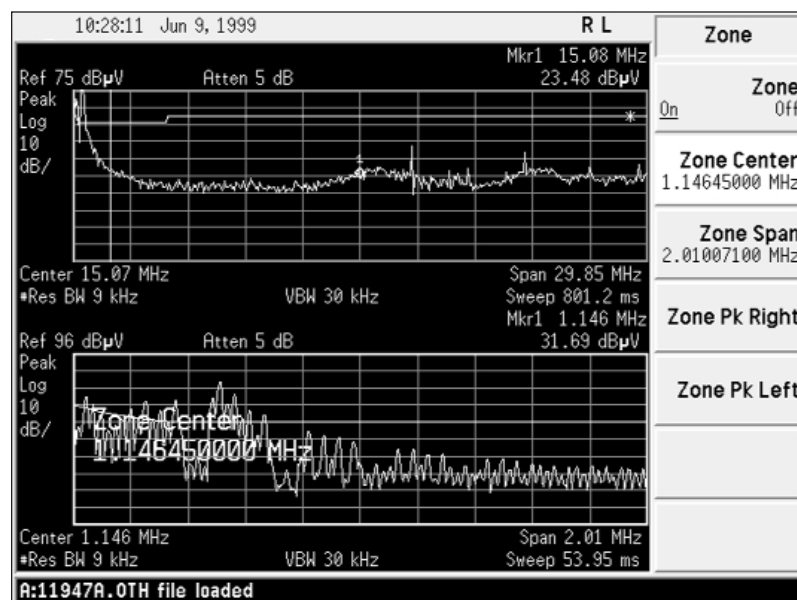


Figure 9. Conducted emissions from EUT

At this point, all the measured signal values are in the internal list of the EMC analyzer. To view the list and determine which signal's quasi-peak levels are above the limit, do the following:

Press [MEASURE], <More>, <Signal list>, <Signal list on>.

Press <List Edit> then <QP ampl on>.
(See Figure 10.)

If there are no quasi-peak values above the limit line (positive values), then your job is done and the product passes conducted emissions tests.

If some of the quasi-peak values are above the limit line, troubleshooting and redesign are required.

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 differential between ambient environment signals (TV, FM, and cellular radio).

1. Arrange the antenna, EUT, and the EMC analyzer as shown in Figure 11. 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 from 3 to 10 meters, which is 10.45 dB.) It is important that the antenna not be placed in the "near field" which is $\lambda/2\pi$ away from the EUT or closer. The Agilent E7400A series has a built-in amplifier with 20 dB gain and 7 dB noise figure. For increased gain, use the Agilent 11909A amplifier with 32 dB gain and 1.8 dB noise figure.

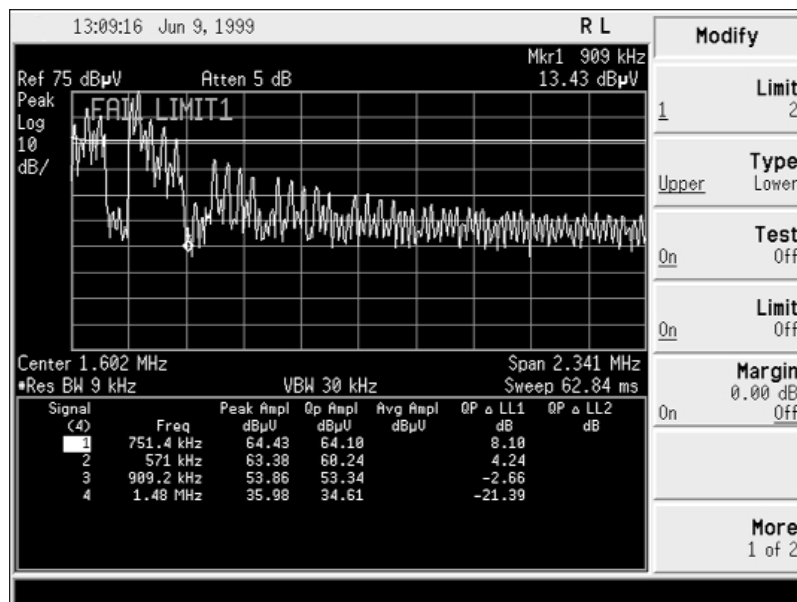


Figure 10. List of measured signals

Precompliance Radiated Measurements

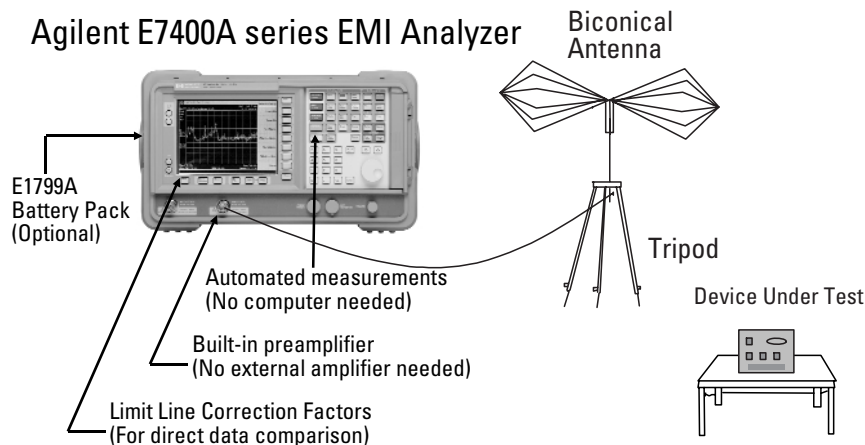


Figure 11. Radiated emissions test setup

2. Set up the EMC analyzer for the correct span, antenna correction factors, and limit line with a margin. Load in the appropriate limit line using the following steps:

Press [Meas Setup], <30–300 MHz>.

Press [FILE], <Load>, <Limits>, and <Limit 1>.

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

Press [ENTER].

3. To load the appropriate antenna correction factor, first determine the test frequency band. The Agilent E7400A series has two preset radiated emissions test bands, 30 MHz to 300 MHz and 200 MHz to 1 GHz. The 30 MHz to 300 MHz band uses a biconical antenna (Agilent 11955A or 11966C) and the 200 MHz to 1 GHz uses a log periodic antenna (Agilent 11966D or 11956A). There is also a broadband antenna (11966P) that covers both bands.

Press [FILE], <Load>, <Corrections>.

Scroll down to the antenna you wish to use, using the knob or the up/down arrows.

Press [ENTER].

- After file is loaded, switch on corrections by pressing [Meas Setup], <more>, <Corrections>, <Modify>, <Corrections on>. To display the correct amplitude units, press <Antenna units>, < $\mu\text{V}/\text{m}$ >.

Typical antenna factors are now loaded into the EMC analyzer. The display is now corrected for the loss of the antenna and the level is measured in dB $\mu\text{V}/\text{m}$, which is a field strength measurement. (See Appendix B for more information on field strength.)

- If an external amplifier is used between the antenna and the EMC analyzer to improve sensitivity, correction factor for the amplifier also must be loaded in to the analyzer. To do this, press:

[FILE], <Load>, <Corrections>.

Scroll to 11909A and press [ENTER].

- If the internal preamplifier is used, press [AMPLITUDE], <More>, <Int preamp on>.

Your display should look similar to Figure 12.

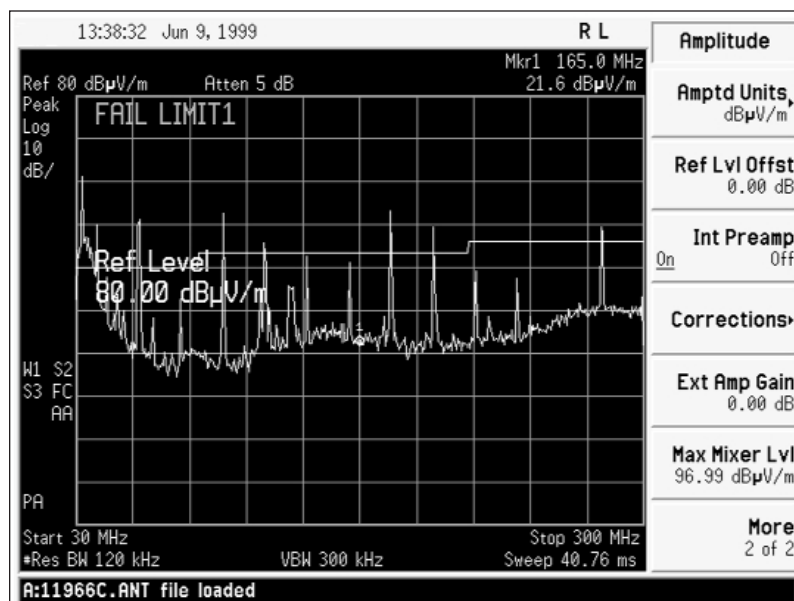


Figure 12. Display with limit line and correction factors

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 ambient environment levels. The ideal situation would be to have all the ambient signals below the limit line. In many cases, ambient signals will be above the limit, so you should measure them and place the results in the internal list of the EMC analyzer.

4.7 Ambient signal measurements

The process for measuring the ambient signals is as follows:

1. Perform a maximum hold on the signals in the band by pressing the following:

[VIEW/TRACE], <MAX HOLD>.

(This function captures most signals, including low PRF signals.)

2. Turn “WINDOW” function on by pressing [SPAN], <Zone>, <Zone on>.
3. Adjust the <ZONE SPAN> and <Zone Center> with the knob to display no more than 20 signals above the limit line on the bottom active trace.
4. Use the “automeasure” function to automatically measure the signals above the limit line:

Press [Measure], <More>, <AUTOMEASURE>, <Start>.

At this point, the EMC analyzer is performing peak and quasi-peak measurements on all signals above the limit line. The signals measured are the ambients (signals produced by other sources) with EUT off. These signals are placed in the internal list. Move the zone marker to the next group of signals on the top trace using the <ZONE CENTER> function and repeat the automatic measurements in Step 4 above. Make sure that all the signals that are above the limit on the upper broad span trace are measured. Press [SPAN], <Zone>, <Zone on> to view the menu with <ZONE CENTER>. Press <ZONE CENTER> and use the knob to move the zone marker to the next group of signals and repeat Step 4 above.

4.8 Placement of EUT for maximum signals

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 ensure that you are measuring the worst case emissions from your device, do the following:

1. Press [MEAS SETUP] and the frequency band of your antenna (for instance, <30 to 300 MHz> for a biconical antenna).
2. At each 45-degree step, note the amplitude of the largest signals. (A screen output to a printer can be very useful.) With a printer connected to the IO port, press [PRINT].
3. On each screen output, mark the position of the EUT.

After all the screens have been captured, compare them to find the position of 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 may be worst-case emissions at 90 degrees and 200 MHz may be worst-case emissions at 270 degrees. In this case, the emissions tests must be performed at both positions. A typical screen output is shown in Figure 13.

If you are not sure whether the signal you are looking at is an ambient or EUT signal, switch the power off on the EUT. If the signal remains, then it is an ambient signal. Repeat this process for the other polarization of the antenna (that is, vertical or horizontal).

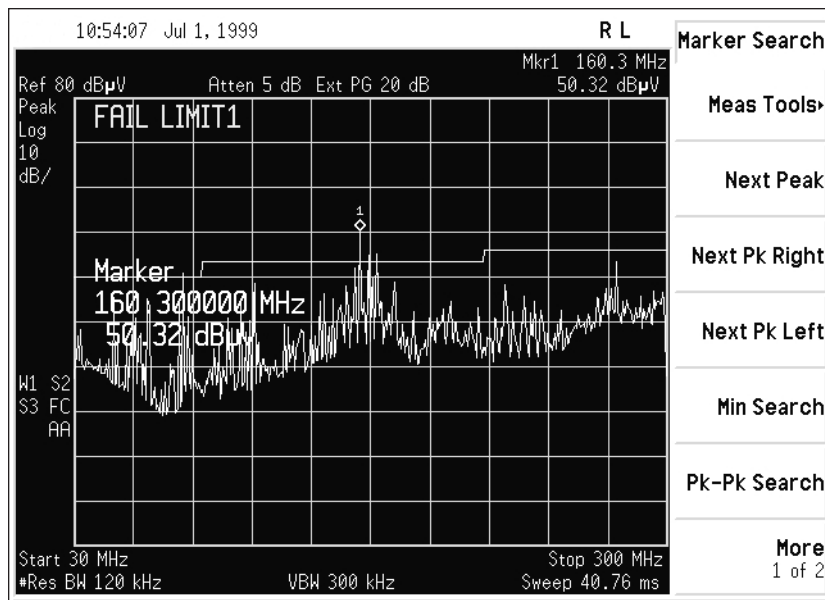


Figure 13. Radiated emissions display

4.9 Ambient plus EUT measurements

With the EUT turned on and oriented to the worst-case position, perform automated tests again as shown below.

1. Press [NEXT WINDOW]. (This activates the upper trace to capture the additional emissions from the EUT.) Press [NEXT WINDOW] again to activate the lower window.
2. Adjust the <ZONE SPAN> with the knob to display no more than 20 signals above the limit line on the bottom active trace. This gives the best frequency accuracy.
3. Use the “automeasure” function to automatically measure the signals above the limit line (above the margin if it was initiated).

Press [MEASURE], <More>, <Automeasure>, <Peak on>, <Quasi-peak on>, <Average off>, <Start>.

At this point, the EMC analyzer is performing a peak and quasi-peak on all signals above the limit line or margin, which is within the zone span area. If necessary, move the zone span to the next group of signals above the limit or margin and perform another automeasure as in Step 2 above.

The signals measured are the ambients and the EUT signals. These signals are also placed in the internal list. Now that you have the ambient signals from the first test and the ambient signals plus the EUT signals from the second group of tests, you can perform a sort on the list looking for duplicates (which will be the ambient signals). To remove the ambient signals from the measurement results, perform the following:

Press [MEASURE], <More>, <Signal list>, <Signal list on>, <Signal marking>, <Select mark>, <Mark all dups>, [RETURN], [RETURN], <Delete signals>, <Delete marked>, <Yes>.

At this point, most of the ambient signals have been deleted from your list. Some ambients may still be present in the internal list because they appeared during only one of the automatic measurements, which means that they would not have had duplicate signals and thus would not have been deleted.

The signals in the list are the peak and quasi-peak values of the EUT emissions and remaining ambient signals. Next, find signals that are above the limit. To do this, first sort the list by quasi-peak values with the highest levels at the top of the list:

Press [MEASURE], <More>, <Signal list>, <signal list on>, <Sort Signals>, <By QP ampl>.

Next, switch the column on that indicates the value of the quasi-peak measurement versus the limit line.

Press [MEASURE], <More>, <Signal list on>.

Press <List edit>, until <QP ampl on> is indicated at the top of the column. (See Figure 14.)

4.10 Evaluating measurement results

If all the values in the QP Δ LL1 column of the internal list are negative, the product emissions are below the limit, and your product passes the radiated emissions requirements and your job is completed.

If some of the values are positive, then the quasi-peak measurements are above the quasi-peak limit and the product fails radiated emissions measurements. To be sure that signals are not ambients, each signal should be remeasured. Use the demodulation function to listen to the signal. AM/FM demodulation is a good tool to use to determine whether or not a signal is an ambient.

To listen to a signal do the following:

Press [MEASURE], <More>, <Signal list on>.

With the signal list on, highlight the signal of interest with the up/down keys.

Press [DET/DEMODO], <Demod>, <FM>, <Speaker on>.

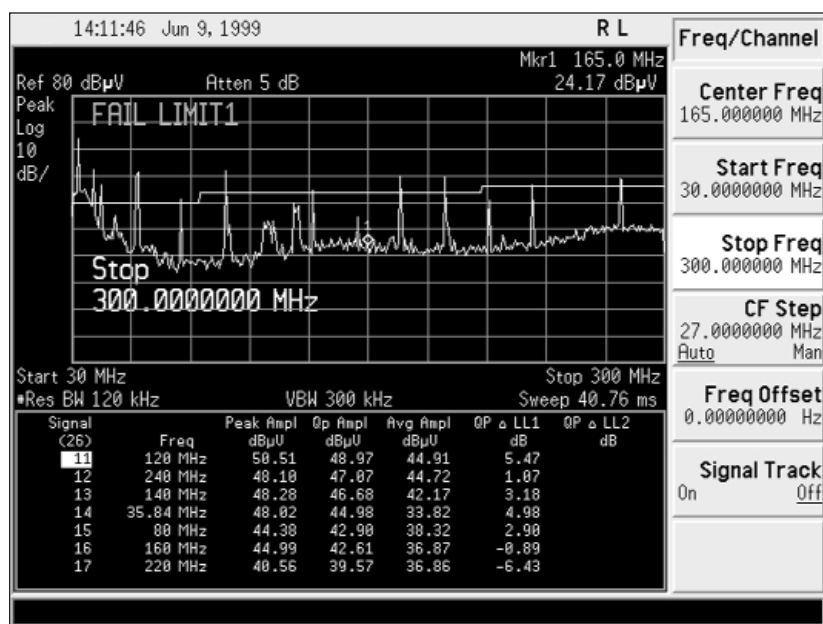


Figure 14. Measurements list compared to limit

Adjust the volume to listen to the signal. If the signal is a local AM, FM, TV, or cellular phone, you should be able to demodulate and listen to the signal. For improved FM demodulation performance, move the signal to within the three top graticules. To do this, press [AMPLITUDE], <Ref level>, [↓] until the signal is in the three top graticules. The demodulation function will enable the operator to hear the audio part of the transmission by dwelling at the marker for a specified length of time (usually 500 msec).

If there is any doubt about the signal being an ambient or an EUT signal, remove the power to the EUT and observe the signal. If the signal remains, it is an ambient. (Note: It may not be convenient to remove the power to the EUT, so using the demodulation function may be the preferred method of identifying ambients.) If you have determined that a signal is an ambient, the next step is to delete the signal.

Press [MEASURE], <More>, <Signal list>, <Signal list on>, <Delete signals>, highlight the ambient signal to be deleted and press <Delete signal>.

After the ambient signals have been deleted from the list, the next step is to develop a report.

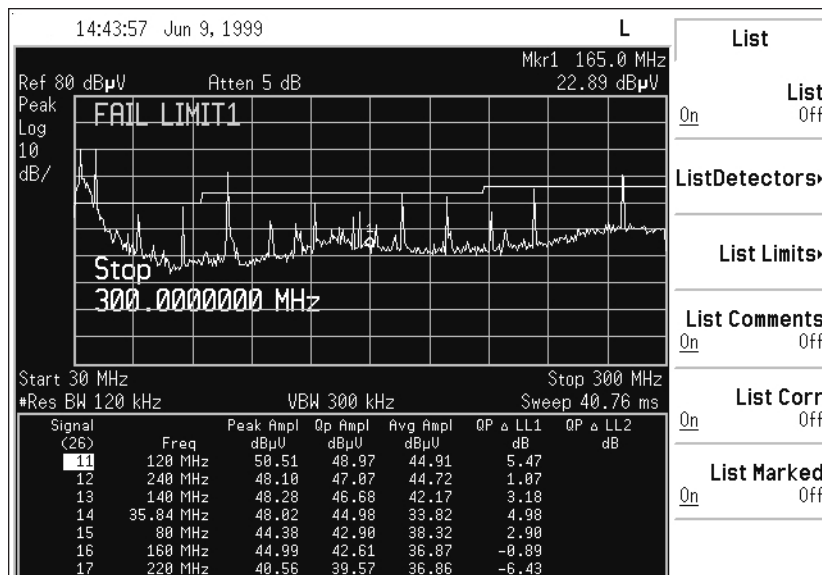
4.11 Report development

The end result of all the above testing is a report. The report is used by the design engineer to correct any problems that are found during the test process. You can assemble a report using the [MEAS SETUP], <Define report> functions. The contents of the report can include a list of signals, and graphical representation of the signals.

To define the report content, press <Define report>, then choose the items you would like to have in the report. Your report can include screen, instrument settings, and signal list information. Examples of screens and lists are shown in Figure 15.

List definition is a separate category. To define the list, press <Define list> and choose the items to be included in the list, such as detector results, limit comparisons, correction factors used, and show marked signals. With the printer attached, press [MEAS SETUP], <More>, <Define report>, <List>, [PRINT]. All the items selected under report definition will be printed sequentially.

The report can be saved as an .htm file. Press [File], <save>, <more>, <report>. Use the alpha editor to change name and press [Enter].



SIGNAL LIST

Signal Number	Frequency (MHz)	Peak (dBuV)	QP (dBuV)	Avg (dBuV)	Comment	Correction (dB)
1	0.751420	64.4	64.1	0.0		10.0
2	0.570990	63.4	60.2	0.0		10.0
3	39.999100	60.6	59.9	57.5		17.0
4	200.008400	58.4	57.4	52.3		16.0
5	179.994200	55.8	55.0	51.6		17.0
6	100.000300	55.8	54.7	50.8		10.0
7	0.909180	53.9	53.3	-56.2		10.0
8	279.999600	53.1	52.0	50.3		25.0
9	59.989500	52.1	51.2	48.5		9.0
10	120.003800	50.6	49.0	44.9		14.0

Figure 15: Example of a printed report

5.0 Problem Solving and Troubleshooting

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

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

1. Connect the diagnostic tools as shown in Figure 16 below.
2. From the report, 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 amplitudes, record the results to disk.
5. Make circuit changes as necessary to reduce the emissions.
6. Remeasure the circuit using the same settings as before.
7. Recall the previous measurement stored to disk and compare the results to the current measurement.

5.1 Diagnostics testing setup

As with emissions testing, the EMC analyzer must be set up to perform diagnostics testing. Corrections for the probe and amplifier must first be loaded into the EMC analyzer. The Agilent 1945A probe kit contains two probes: one for the 9 kHz to 30 MHz frequency range and one for the 30 MHz to 1 GHz frequency range. Connect the probe for the appropriate frequency range and load in the correction factors by pressing the following:

[FILE], <Load>, <Corrections>. Scroll to 11940A or 11941A and press [ENTER]. Switch on the corrections by pressing [Meas Setup], <more>, <corrections>, <corrections on>, <modify>, <select antenna>, <corrections on>.

The next step is to load in the correction factors for the amplifier by pressing the following:

[FILE], <Load>, <Corrections>. Scroll down to the 11909A and press [ENTER]. Select the correct units by [Meas Setup], <more>, <Corrections>, <modify>, <antenna units>, < $\mu\text{A}/\text{m}$ >

The EMC analyzer is now calibrated in $\text{dB}\mu\text{A}/\text{m}$, which is magnetic field strength units.

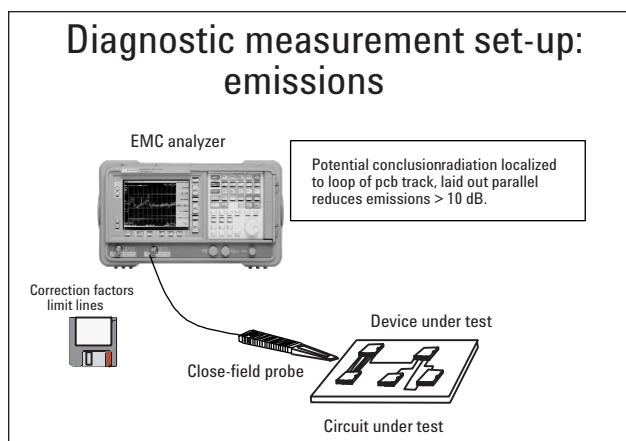


Figure 16. Diagnostics setup interconnection

Note: The Agilent E7401A has a built-in preamp. If it is found that additional gain is needed, the Agilent 11909A is recommended.

5.2 Problem isolation

Using the report generated from the conducted and radiated emissions test, tune the EMC analyzer 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 as you isolate the source of the emissions. After you have isolated the source of the

emissions, record the location and store the display to disk. To store the display, insert a formatted disk into Drive A and press the following:

[FILE], <Save>¹, <Trace >, <1>, <Trace + state>.

Use the alpha editor to name the trace, and press [ENTER].

Figure 17 shows the trace saved onto disk.

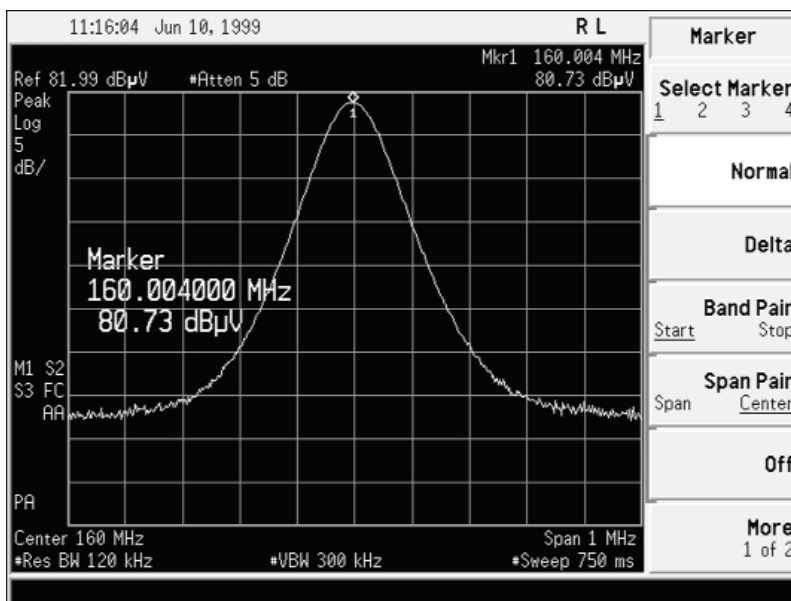


Figure 17. Isolated signal source display

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, remeasure the results, comparing the old trace before redesign to the new trace by recalling the saved trace off the card. To recall the trace, press the following:

[FILE], <Load>, <Trace>.

Scroll down to the trace you previously stored and press [ENTER].

The trace is recalled into the Trace 1 area in the VIEW mode.

Press [VIEW/TRACE], <Trace 2>, <Clear write>.

With your probe on the trouble spot, compare emissions before and after repairing the problem. (See Figure 18.)

As you can see from the delta marker measurement, the new trace after the product redesign is 10 dB below the previously stored trace. There is a one-to-one correlation between changes in close field measurements and changes in far field measurements. For example, if you note a 10 dB change in measurements made by a close field probe, you will note a 10 dB change when you perform a far field measurement using an antenna and an EMC analyzer.

Conversely, if you find that the radiated emissions from your EUT are failing a limit by 10 dB, then you will need to do some redesign 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.

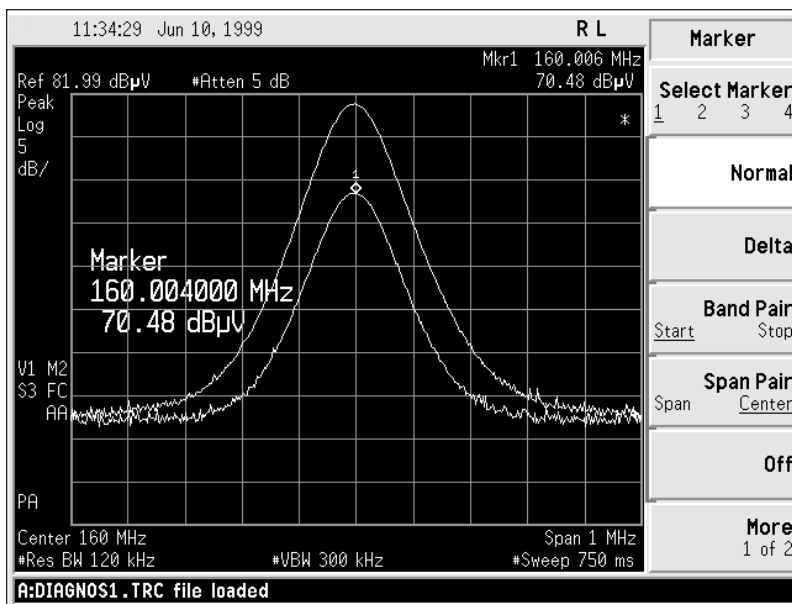


Figure 18. Emissions reduction comparison display

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 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 that 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.

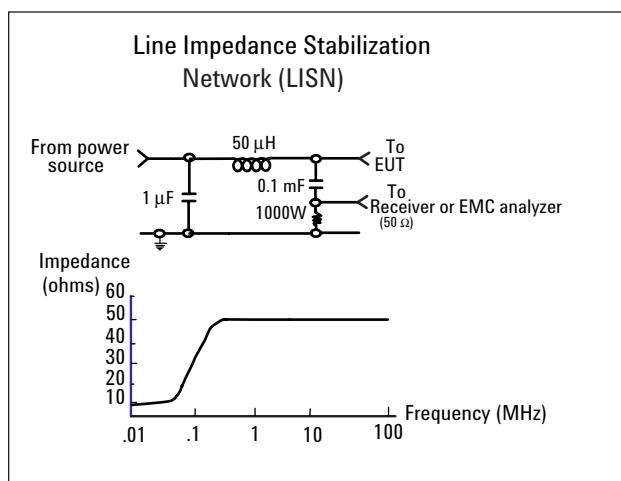


Figure A-1. Typical LISN circuit diagram

The 1 μ F in combination with the 50 μ H inductor is the filter that isolates the mains from the EUT. The 50 μ H inductor isolates the noise generated by the EUT from the mains. The 0.1 μ F 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

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

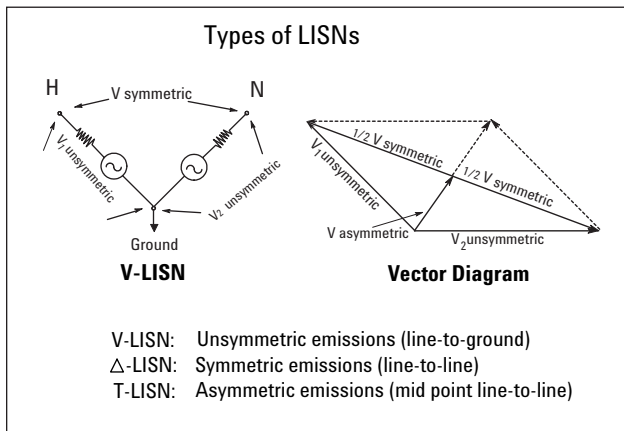


Figure A-2. Three different types of LISNs

Appendix B: Antenna Factors

B1.0 Field strength units

Radiated EMI emissions measurements measure the electric field. The field strength is calibrated in dB μ V/m. Field strength in dB μ V/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)

$$P_D = P_t / 4\pi r^2 \quad R = 120\pi\Omega$$

$$P_D = E^2 / R$$

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

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

Far field¹ is considered to be $>\lambda/2\pi$

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.

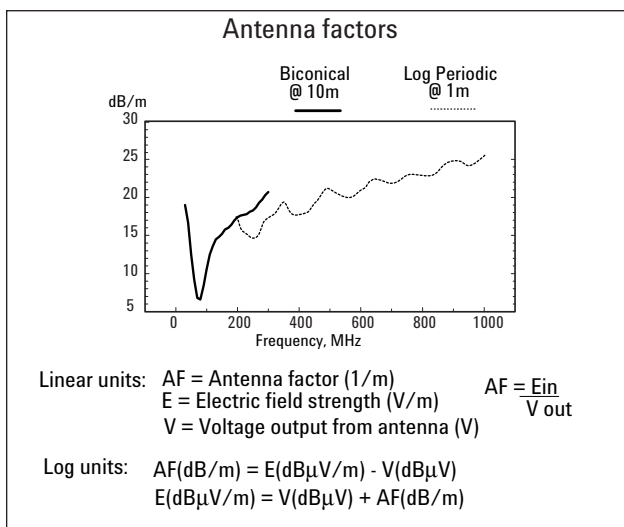


Figure B-1. Typical antenna factor shapes

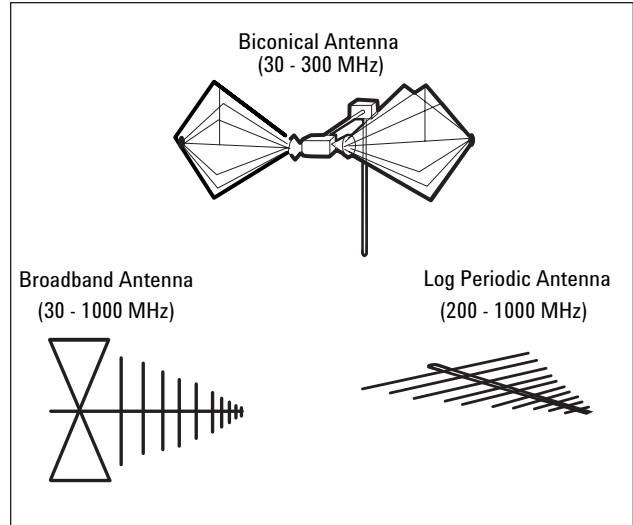


Figure B-2. Antennas used in EMI emissions measurements

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)

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

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 dB μ V or dB μ A. The relationship of dB μ V and dBm is as follows:

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

This is true for an impedance of 50 Ω .

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

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

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.)

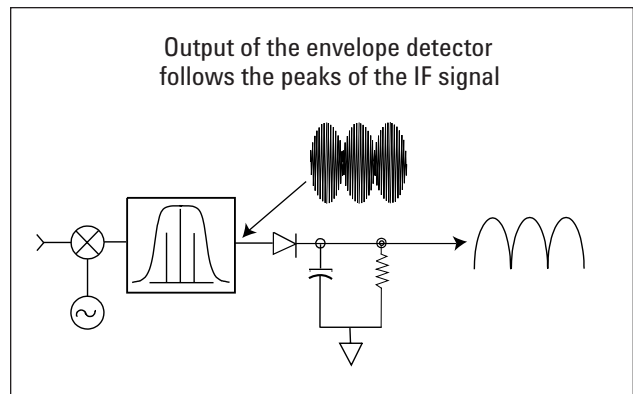


Figure D-1. Peak detector diagram

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.

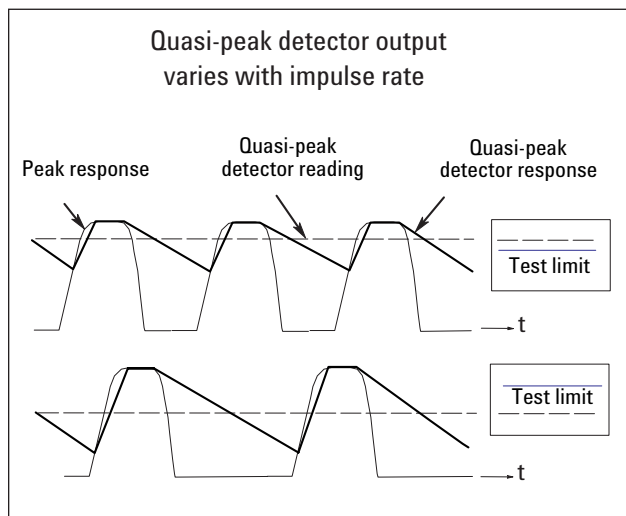


Figure D-2. Quasi-peak detector response diagram

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 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.

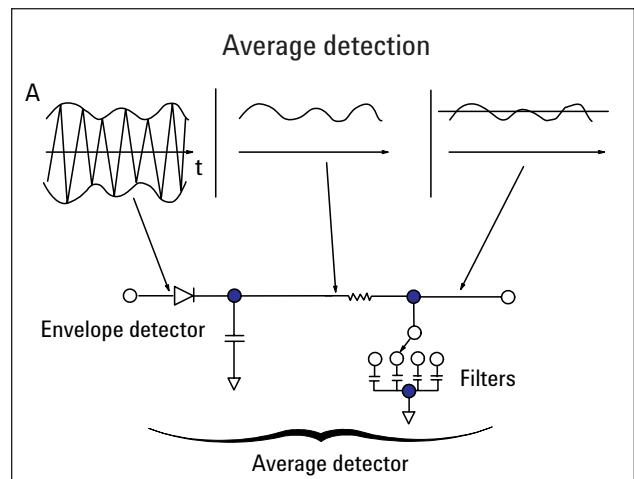


Figure D-3. Average detection response diagram

Appendix E: EMC Regulatory Agencies

The following is a listing of addresses 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

CCIR

ITU, General Secretariat, Sales Service

Place de Nation
1211 Geneva, Switzerland

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

Belgium

Comite Electrotechnique Belge

3 Galerie Ravenstein, Boite 11
B-1000 Bruxelles
Telephone: +32 2 512 00 28
Fax: +32 2 511 29 38

Canada

Standards Council of Canada

Standards Sales Division

350 Sparks Street, Suite 1200
Ottawa, Ontario K1P 6N7
Telephone: 613 238 3222
Fax: 613 995 4564

Canadian Standards Association (CSA)

178 Rexdale Boulevard
Rexdale (Toronto), Ontario M9W 1R3
Telephone: 416 747 4044
Fax: 416 747 2475

Denmark

Dansk Elektroteknisk Komite

Strandgade 36 st
DK-1401 Kobenhavn K
Telephone: +45 31 57 50 50
Fax: +45 31 57 63 50

France

Comite Electrotechnique Francais

UTE CEDEX 64
F-92052 Paris la Defense
Telephone: +33 1 47 68 50 20
Fax: +33 1 47 89 47 75

Germany

VDE CERLAG GmbH

Austieferungsstelle

Merianstrasse 29
D-6050 OFFENBACH a.M.
Telephone: +49 69 8306-1
Fax: +49 69 83 10 81

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

Italy

Comitato Eletrotecnico Italiano

Viale Monza 259
I-20126 Milano MI
Telephone: +39 2 25 77 31
Fax: +39 2 25 773 222

Japan

Japanese Standards Association

1-24 Akasaka 4
Minato-Ku
Tokyo 107
Telephone: +81 3 583 8001
Fax: +81 3 580 14 18

Appendix E: EMC Regulatory Agencies, continued

Netherlands

Nederlands Normalisatie-Instituut

Afd. Verdoop en Informatie

Kalfjeslaan 2, PO Box 5059

2600 GB Delft

NL

Telephone: +31 15 69 03 90

Fax: +31 15 69 01 90

Norway

Norsk Elektroteknisk Komite

Harbizalleen 2A

Postboks 280 Skoyen

N-0212 Oslo 2

Telephone: +47 2 52 69 50

Fax: +47 2 52 69 61

South Africa

South African Bureau of Standards

Electronic Engineering Department

Private Bag X191

Pretoria

0001 Republic of South Africa

Spain

Comite Nacional Espanol de la CEI

Francisco Gervás 3

E-28020 Madrid

Telephone: +34 1 270 44 00

Fax: +34 1 270 28 55

Sweden

Svenka Elektriska Kommissionen

PO Box 1284

S-164 28 Kista-Stockholm

Telephone: +46 8 750 78 20

Fax: +46 8 751 84 70

Switzerland

Swiss Electromechanical Committee

Swiss Electromechanical Association

Seefeldstrasse 301

CH-8008 Zurich

Telephone: +41 1 384 91 11

Fax: +41 1 55 14 26

United Kingdom

British Standards Institution

BSI Sales Department

Linford Wood

Milton Keynes MK14 GLE

Telephone: +44 908 22 00 22

Fax: +44 908 32 08 56

British Defence Standards

DEF STAN

Ministry of Defence

Northumberland House

Northumberland Ave

London WC2N 5 BP

Telephone: +01 218 9000

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

FCC Rules and Regulations

Technical Standards Branch

2025 M Street N.W.

MS 1300 B4

Washington DC 20554

Telephone: 202 653 6288

FCC Equipment Authorization Branch

7435 Oakland Mills Road

MS 1300-B2

Columbia, MD 21046

Telephone: 301 725 1585

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, 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

A shielded room that is lined with radio-absorbing material to reduce reflections from all internal surfaces. Fully lined anechoic chambers have such material on all internal surfaces—walls, ceiling, and floor. It's also called a “fully anechoic chamber.” A semi-anechoic chamber is a shielded room that has absorbing material on all surfaces except the floor.

Antenna (Aerial)

1. A means for radiated or receiving radio waves.
2. A transducer that 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 that, 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 that 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

An antenna-balancing device that facilitates use of coaxial feeds with a symmetrical antenna such as a dipole.

Broadband emission

Broadband is the definition for an interference amplitude when several spectral lines are within the RFI receiver's 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

An electrical circuit for preventing test signals that 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 margin of safety in the intended operational environment, at designed levels of efficiency, without degradation due to interference.
2. The ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances into that environment or into other equipment.

Electromagnetic interference

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 one-half—where l is the wavelength 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

Having properties of equal values in all directions.

Monopole

An antenna consisting of a straight conductor, usually not more than one-quarter wavelength 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 that is open, flat terrain at a distance far enough away from buildings, electric lines, fences, trees, underground cables, and pipelines 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—that 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

The characteristic of electronic equipment that permits undesirable responses when subjected to electromagnetic energy.

By internet, phone, or fax, get assistance with all your test and measurement needs.

Online Assistance

www.agilent.com/find/assist

Phone or Fax

United States:

(tel) 1 800 452 4844

Canada:

(tel) 1 877 894 4414

(fax) (905) 206 4120

Europe:

(tel) (31 20) 547 2323

(fax) (31 20) 547 2390

Japan:

(tel) (81) 426 56 7832

(fax) (81) 426 56 7840

Latin America:

(tel) (305) 269 7500

(fax) (305) 269 7599

Australia:

(tel) 1 800 629 485

(fax) (61 3) 9272 0749

New Zealand:

(tel) 0 800 738 378

(fax) (64 4) 495 8950

Asia Pacific:

(tel) (852) 3197 7777

(fax) (852) 2506 9284

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