Agilent AN 1328
Making Precompliance Conducted and Radiated Emissions Measurements with EMC Analyzers
Application Note

Agilent E7400A Series

Agilent Technologies
Innovating the HP Way
Table of Contents

3  1.0 Introduction to Precompliance Measurements
4   1.1 Precompliance measurements versus full compliance measurements
5  2.0 EMI Precompliance Systems
6  3.0 Precompliance Measurements Process
9  4.0 Emissions Testing
9   4.1 Introduction
9   4.2 Conducted emissions measurements preparation
13  4.3 Performing conducted emissions measurements
13   4.4 Starting the conducted measurements process
13       4.4.1 Overload test
14       4.4.2 Signal measurements
15   4.5 Radiated emissions measurements preparation
17   4.6 Measuring radiated emissions
18   4.7 Ambient signal measurements
18   4.8 Placement of EUT for maximum signals
19   4.9 Ambient plus EUT measurements
20   4.10 Evaluating measurement results
21   4.11 Report development
23  5.0 Problem Solving and Troubleshooting
23   5.1 Diagnostics testing setup
24   5.2 Problem isolation
26  Appendix: A Line Impedance Stabilization Networks (LISN)
26   A1.0 Purpose of a LISN
26       A1.1 LISN operation
27       A1.2 Types of LISNs
27   A2.0 Transient limiter operation
28  Appendix B: Antenna Factors
28   B1.0 Field strength units
28       B1.1 Antenna factors
28       B1.2 Types of antennas used for commercial radiated measurements
29  Appendix C: Basic Electrical Relationships
29  Appendix D: Detectors Used in EMI Measurements
29   D1.0 Peak detector
29       D1.1 Peak detector operation
30   D2.0 Quasi-peak detector
30       D2.1 Quasi-peak detector operation
30   D3.0 Average detector
30       D3.1 Average detector operation
31  Appendix E: EMC Regulatory Agencies
33  Glossary of Acronyms and Definitions
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).
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 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.

Figure 2. Electromagnetic compatibility between products
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 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).

**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

<table>
<thead>
<tr>
<th>Emissions regulations (summary)</th>
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</thead>
<tbody>
<tr>
<td><strong>FCC</strong></td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td>12</td>
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</tbody>
</table>
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)
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.
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.
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).

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>.

Conducted emissions measurements are easier than ever!

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>.
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.
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].
4. 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>, <µV/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 dBuV/m, which is a field strength measurement. (See Appendix B for more information on field strength.)

5. 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].

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

Your display should look similar to Figure 12.

### 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.

![Figure 12. Display with limit line and correction factors](image)
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 ambient 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).
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 ambient 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 dup>, [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/DEMOD], <Demod>, <FM>, <Speaker on>.

![Figure 14. Measurements list compared to limit](image-url)
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

<table>
<thead>
<tr>
<th>Signal Number</th>
<th>Frequency (MHz)</th>
<th>Peak (dBuV)</th>
<th>CP (dBuV)</th>
<th>Avg (dBuV)</th>
<th>Comment</th>
<th>Correction (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.751420</td>
<td>64.4</td>
<td>64.1</td>
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<td>63.4</td>
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</table>

**Figure 15:** Example of a printed report
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>, <μA/m>

The EMC analyzer is now calibrated in dBμA/m, which is magnetic field strength units.

5.0 Problem Solving and Troubleshooting

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.

---

1. Insure that the path is "A."
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](image)

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 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 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**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-LISN</td>
<td>Unsymmetric emissions (line-to-ground)</td>
</tr>
<tr>
<td>Δ-LISN</td>
<td>Symmetric emissions (line-to-line)</td>
</tr>
<tr>
<td>T-LISN</td>
<td>Asymmetric emissions (mid point line-to-line)</td>
</tr>
</tbody>
</table>
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:

\[ P_t = \text{total power radiated from an isotropic radiator} \]

\[ P_D = \text{the power density at a distance } r \text{ from the isotropic radiator (far field)} \]

\[ P_D = \frac{P_t}{4\pi r^2} \quad R = 120\pi\Omega \]

\[ E = \frac{P_t}{4\pi r^2} \]

\[ \frac{E^2}{R} = \frac{P_t}{4\pi r^2} \]

\[ E = \left( \frac{P_t \times 30}{r} \right)^{1/2} (V/m) \]

Far field 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.

\[ \text{Linear units: } AF = \text{Antenna factor (1/m)} \]

\[ E = \text{Electric field strength (V/m)} \]

\[ V = \text{Voltage output from antenna (V)} \]

\[ \text{Log units: } AF(dB/m) = E(dB\mu V/m) - V(dB\mu V) \]

\[ E(dB\mu V/m) = V(dB\mu V) + AF(dB/m) \]

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)

Figure B-1. Typical antenna factor shapes

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

\[ \text{decibel} = dB = 10 \log \left( \frac{P_2}{P_1} \right) \]

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:

\[ dB = 20 \log \left( \frac{V_2}{V_1} \right) \]

A unit of measure used in EMI measurements is dB\(\mu V\) or dB\(\mu A\). The relationship of dB\(\mu V\) and dB\(m\) is as follows:

\[ \text{dB}\mu V = 107 + \text{PdBm} \]

This is true for an impedance of 50 Ω.

Wave length (\( \lambda \)) is determined using the following relationship:

\[ \lambda = 3 \times 10^8 / f \text{ (Hz)} \text{ or } \lambda = 300 / f \text{ (MHz)} \]
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.
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**  
Comité 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 MSW 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**  
Comité 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  
1-20126 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 Gervas 3
E-28020 Madrid
Telephone: +34 1 270 44 00
Fax: +34 1 270 28 55

Sweden
Svenka Elecktriska Kommissionen
PO Bow 1284
S-164 28 Kista-Stockholm
Telephone: +46 8 750 76 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
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 λ 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) 0 800 739 378
(fax) (64 4) 495 8950

Asia Pacific:
(tel) (852) 3197 7777
(fax) (852) 2566 9284

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