HEWLETT® PACKARD

Cookbook for EMC Precompliance Measurements

A Guide to Making Precompliance Conducted and Radiated Emissions Measurements with Spectrum Analyzers and EMC Analyzers

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1.0 Introduction to Precompliance Measurements

Note: precompliance measurements can be made with a variety of spectrum analyzers and EMC analyzers having the appropriate detectors and bandwidth filters. In this application note, detailed measurement procedures are provided for HP 8590EM series EMC analyzers. However, these procedures can be adapted to other instruments.

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 a costly 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 to preproduction units. Figure 1 below shows a typical product development cycle.

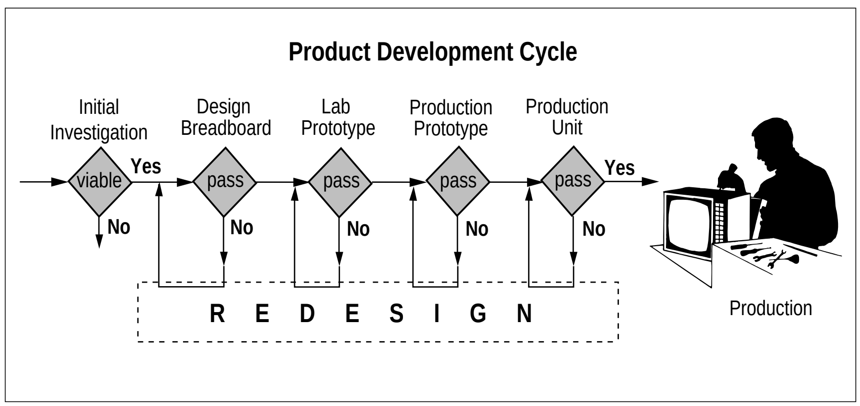


Figure 1. A typical product development cycle.

Many manufacturers use EMI precompliance measurement systems to perform conducted and radiated EMI emissions tests prior to having the product sent 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 are 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 new 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.

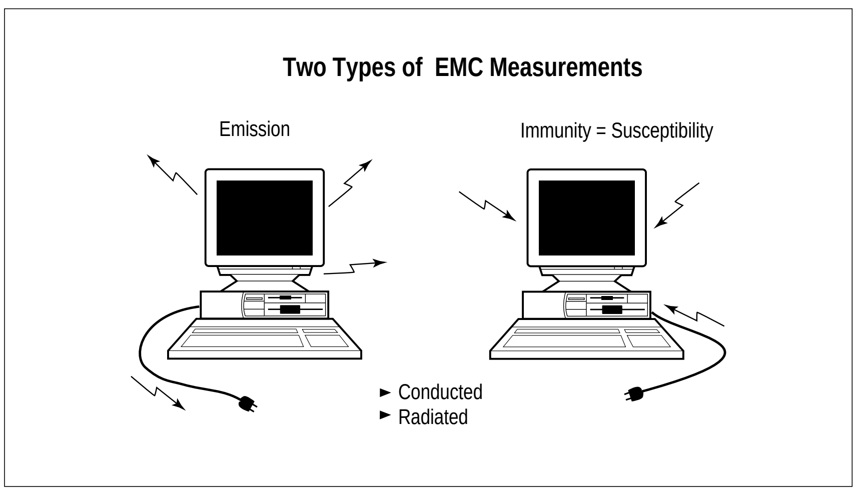


Figure 2. Electromagnetic compatibility between products.

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 CISPR[1] 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 minimize the number of reflective objects in the measurement area, the better the accuracy of the measurements.

2.0 EMI Precompliance Systems

The contents of a precompliance test system (the HP 84110EM preproduction evaluation system, for example) includes an EMC analyzer or spectrum 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).

1. Comite International Special des Perturbations Radioelectriques

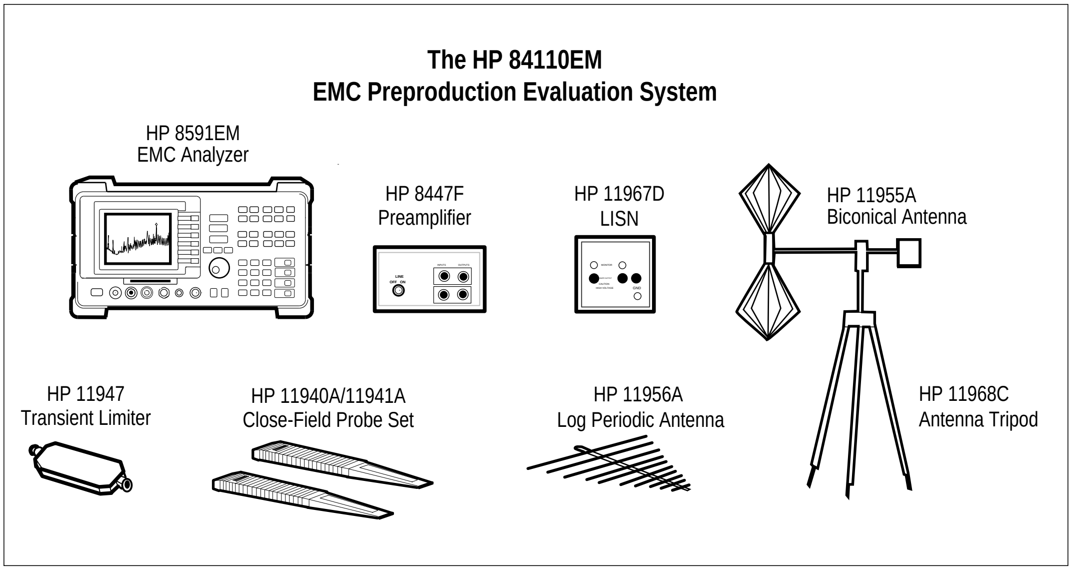


Figure 3. Components of a preproduction evaluation system.

3.0 Precompliance Measurements Process

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

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

2. What is the classification of the product (i.e., 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, 1b, and 1c below to choose the requirement for your product. When in doubt, call the appropriate agency for final conformation of the applicable requirement. (A list of phone numbers is included in the Appendix E.)

International Regulations Summary (Emissions)

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

Table 1a. Comparison of regulatory agency requirements.

European Norms that Exist Now

Equipment Type	Emissions
■ Generic Equipment ■ Residential ■ Light Industrial	EN 50081-1
■ Industrial	EN 50081-2
■ Information Technology Equipment (ITE)	EN 55022
■ Industrial, Scientific, Medical Products (ISM)	EN 55011

Table 1b. Major European requirements.

European Norms Detail Description

EN55011 (CISPR 11)

Industrial, Scientific, and Medical Products.
Class A: Used in establishments other than domestic areas.
Class B: Suitable for use in domestic establishments.
Group 1 Laboratory, medical, and scientific equipment.
(For example: signal generators, measuring receivers, frequency counters, spectrum analyzers, switching mode power supplies, weighing machines, and electronic microscopes.)

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

EN55014 (CISPR 14)

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

	(ROM card file names)
Household and similar appliances (conducted)	EN014-HL
Household and similar appliances (radiated)	EN014-HH
Motors < 700W (conducted)	EN014-P1
Motors < 700W (radiated)	EN014-P4
Motors <1000W (conducted)	EN014-P2
Motors <1000W (radiated)	EN014-P5
Motors >1000W (conducted)	EN014-P3
Motors >1000W (radiated)	EN014-P6

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.

FCC
(Federal Communications Commission)

Equipment	FCC
■ Broadcast receivers	Part 15
■ Household appliances/tools	
■ Fluorescent lights/luminaries	
■ Information Technology Equipment (ITE)	
■ Industrial, Scientific, Medical Products (ISM)	Part 18
■ Conducted measurements: 450 kHz - 30 MHz	
■ Radiated measurements: 30 MHz - 1000 MHz, 40 GHz	

Table 1c. FCC requirements summary.

Federal Communications Commission Equipment Detailed Description

FCC Part 15

Radio frequency devices—unintentional radiators (For example, TV broadcast receivers, FM broadcast receivers, CB receivers, scanning receivers, TV interface device, cable system terminal device, Class B personal computers and peripherals, Class B digital devices, Class A digital devices and peripherals, external switching power supplies.

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

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

4.0 Emissions Testing

4.1 Introduction

After the appropriate regulations have been identified, the next step is to setup the test equipment and perform radiated and conducted emissions tests. The first group of tests to perform are 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 setup the equipment and the equipment under test.

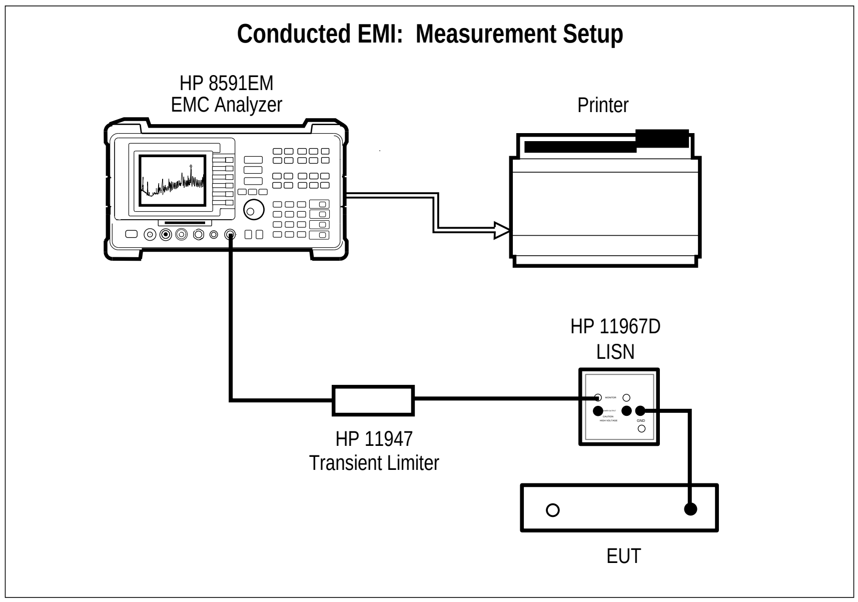


Figure 4. Conducted measurements interconnection.

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. Setup the correct frequency range. Press [SETUP], <150 kHz - 30 MHz>.

4. Select and load the limit line from the ROM card 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:

   [SETUP], <More>, <Limit Lines>, <RECALL LIMITS>, scroll down and highlight the required limit line (i.e., lEN022_BC which is the conducted limits for Class B products). Press <LOAD FILE>. (See Figures 5a and 5b)

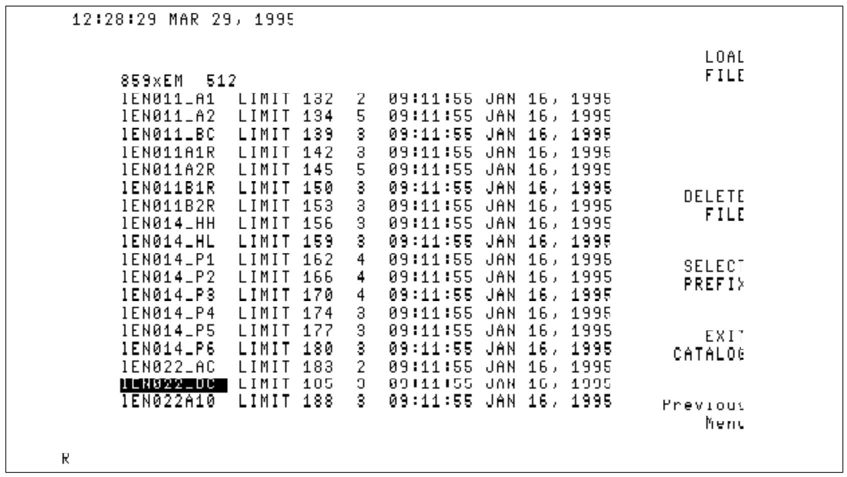


Figure 5a. Partial list of regulatory limits.

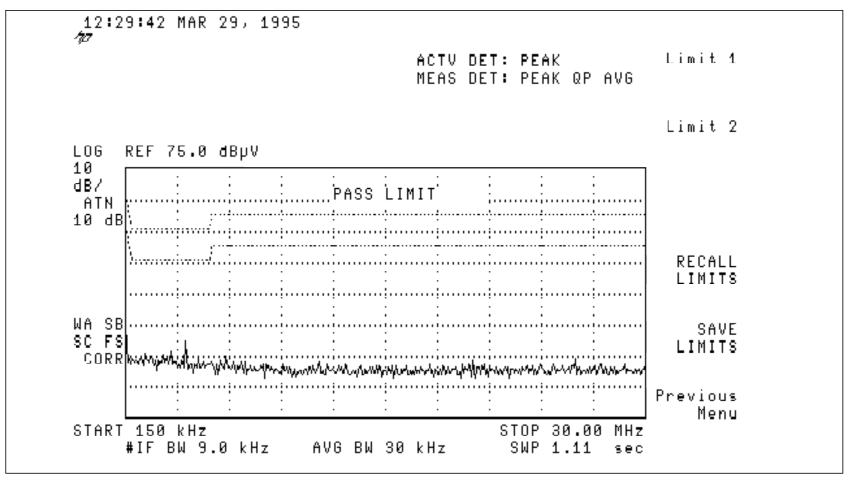


Figure 5b. Regulatory limits displayed.

5. Correct for the LISN. The ROM card contains typical correction factors. To correct the display for the LISN press the following buttons:

   [SETUP], <More>, <Correctn factors>, <Antenna Factors>, <RECALL ANTENNAS>. Scroll down to the LISN you are using. Press <LOAD FILE>. Hewlett-Packard offers two LISNs, HP 11967C (25 amps) and HP 11967D (10 amps). (See Figures 6a and 6b)

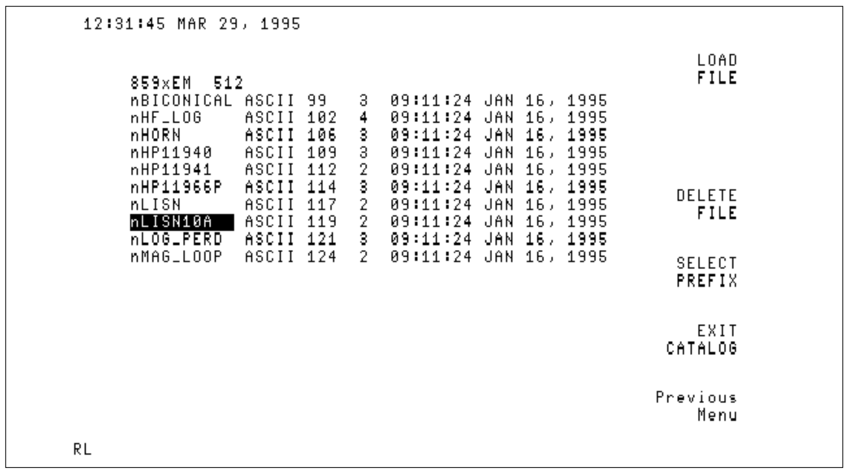


Figure 6a. List of typical transducers.

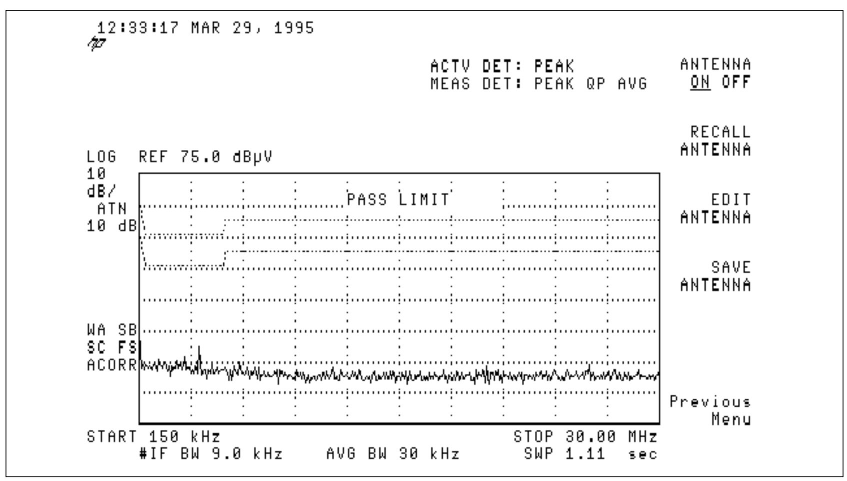


Figure 6b. Display corrected for LISN factors.

6. Correct the display for the HP 11947A transient limiter by pressing the following buttons:

   [SETUP], <More>, <Correctn Factors>, <Other Factors>, <RECALL OTHER>, select HP 11947A and <LOAD FILE>. (See Figures 7a and 7 b)

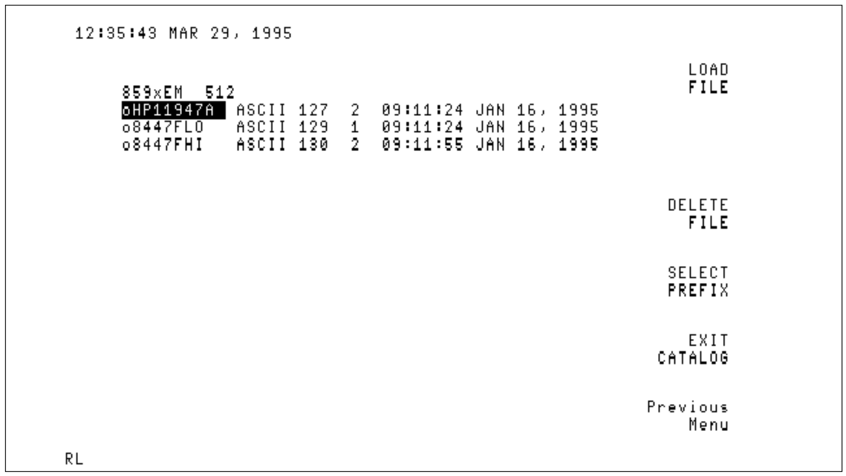


Figure 7a. List of amplifiers and limiter.

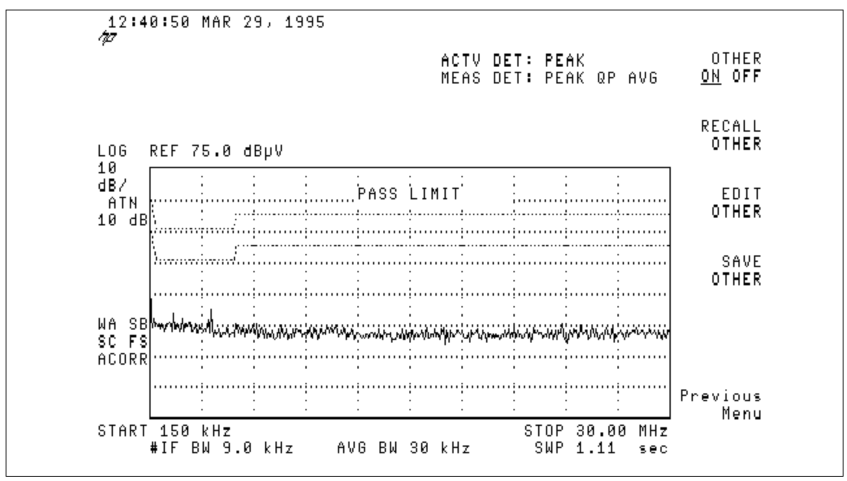


Figure 7b. Display corrected for limiter losses.

4.3 Performing Conducted Emissions Measurements

At this point the EMC analyzer is setup 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).

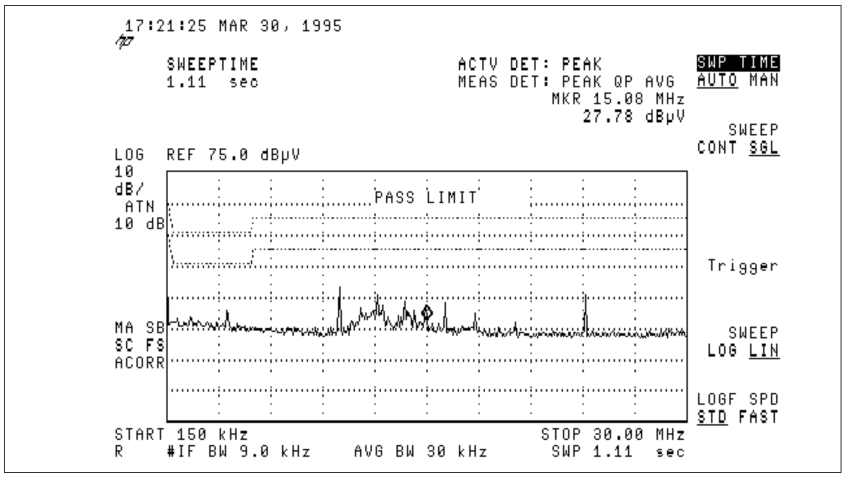


Figure 8. Noise picked up by power cord with EUT off.

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 Measurement 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. One of the ways to take a closer look at the lower end of the band is to switch to log frequency sweep. Log sweep expands the lower decades.

Press [FREQUENCY], <SWEEP LOG>

The display is in a log frequency format. As you can see on the display, the signals at the lower frequencies are more defined in log swept mode than in linear frequency mode.

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 very high causing errors in amplitude measurements. To test for this condition do the following: Press [AMPLITUDE], <ATTN MAN>, up arrow 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 over loaded. If the amplitude of the signal does change then the input is overloaded and additional attenuation must be added.

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 [SETUP], <more>, <Detectors>, underline <DETECTORS, PK, QP>. Press [WINDOWS ON], use <ZONE CENTER> and <ZONE SPAN> to show the signals of interest in the active trace. (See Figure 9)

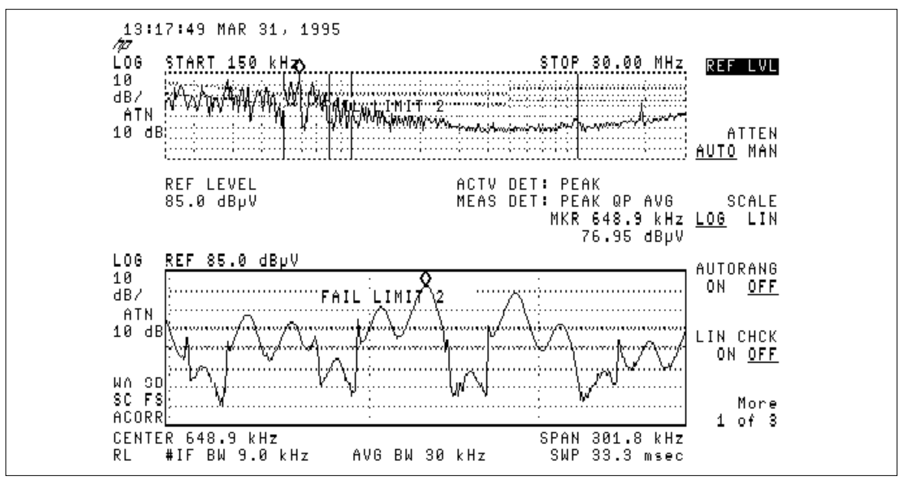


Figure 9. Conducted emissions from EUT in log format.

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

> Press <MEASURE AT MKR>. After the measurement is completed, the signal frequency, peak, and quasi-peak amplitudes will appear in the box above the display.
> Press <ADD TO LIST>

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

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 <SIGNAL LIST ON>

Press <VIEW DELTA> until VIEW QP Δ LIM 1 is shown.
(See Figure 10)

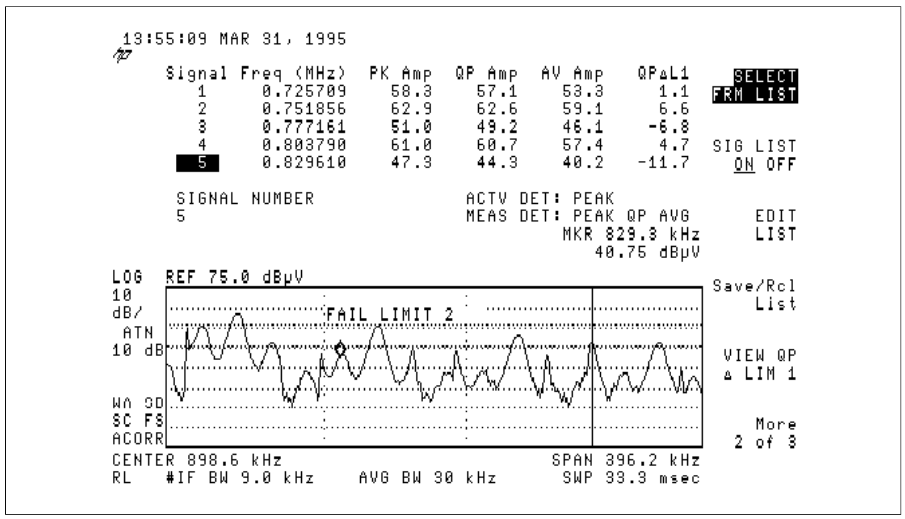


Figure 10. List of measured signals.

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 straight forward 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 (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 is not placed in the "near field" which is $\lambda/2\pi$ away from the EUT or closer.

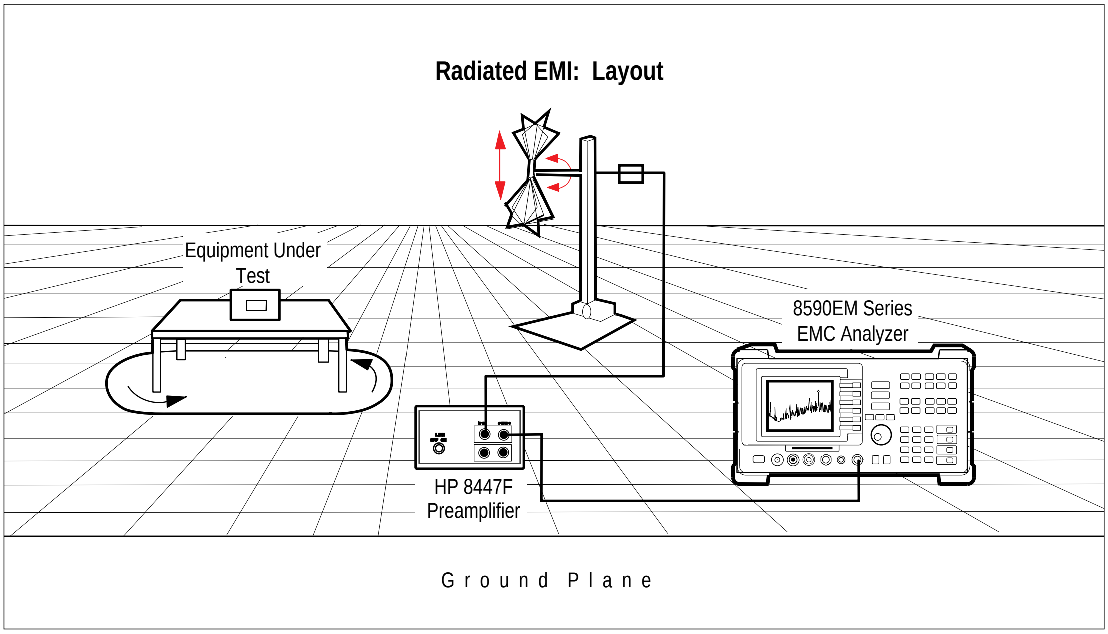


Figure 11. Radiated emissions test setup.

2. Setup 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 [SETUP], <more>, <Limit Lines>, and <RECALL LIMIT].

   Scroll down to the radiated emissions limit determined in Table 1 (i.e., FCC15B3M).

   Press <LOAD FILE>

3. To load the appropriate antenna correction factor, first determine the test frequency band. The HP 8590EM 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 and the 200 MHz to 1 GHz uses a log periodic antenna. There is also a broadband antenna (HP 11966P), that covers both bands.

   Press [SETUP], <more>, <Correctn Factor>, <Antenna Factors>, <RECALL <ANTENNA>.

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

   Press <LOAD FILE>

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.)

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

   [SETUP], <more>, <Correctn Factor>, <Other Factor>, <RECALL OTHER>

   Scroll to 8447HI and press <LOAD FILE>.

Your display should look similar to Figure 12.

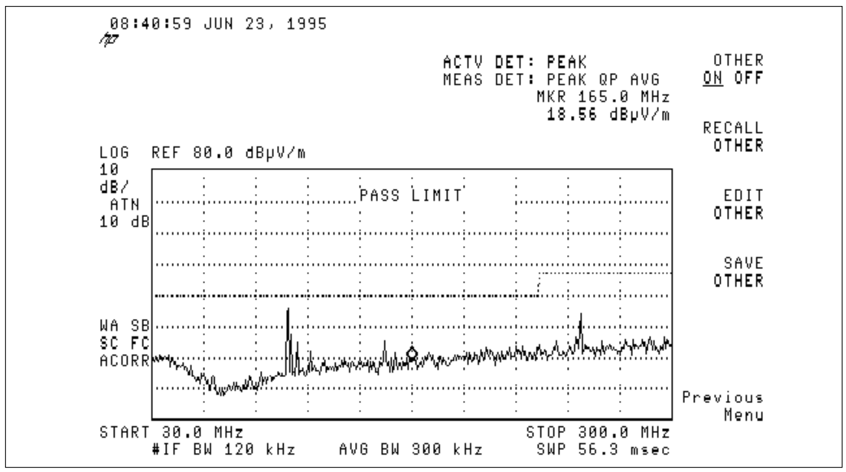


Figure 12. Display with limit line and correction factors.

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 follow:

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

   [TRACE], <MAX HOLD A>

(This function captures most signals including low PRF signals)

2. Turn “WINDOW” function on by pressing [ON] under the [WINDOWS] area.

3. Adjust the <ZONE SPAN> 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 [TEST], <More>, <More>, <AUTOMEASURE>.

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 [ON] under the WINDOW area 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 [SETUP] and the frequency band of your antenna (i.e., <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 [COPY].)

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 degree 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 (i.e., vertical or horizontal).

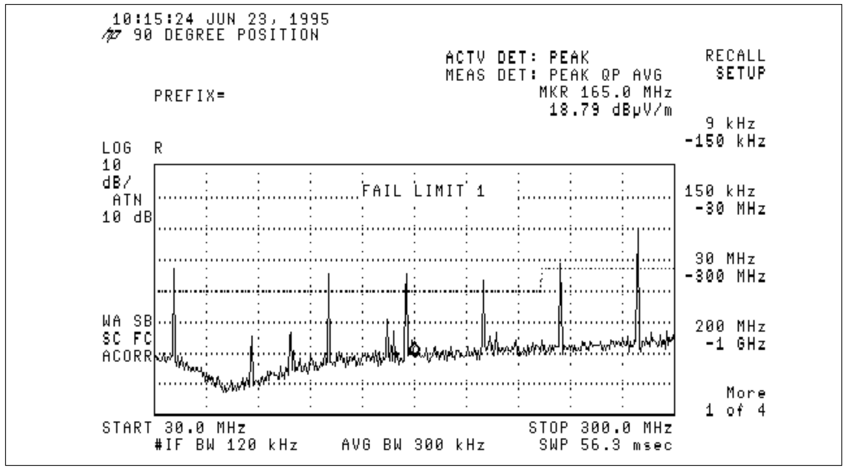


Figure 13. Radiated emissions display.

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] under [WINDOW] (This activates the upper trace to capture the additional emissions from the EUT.) Press [NEXT] 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 auto measure function to automatically measure the signals above the limit line (above the margin if it was initiated).

   Press [TEST], <More>, <More>, <AUTOMEASURE>.

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 [TEST], <More>, <EDIT LIST>, <Signal Marking>, <Selectv Mark>,
<MARK ALL DUPLICAT>, and <DELETE MARKED>.
(See Figure 14)

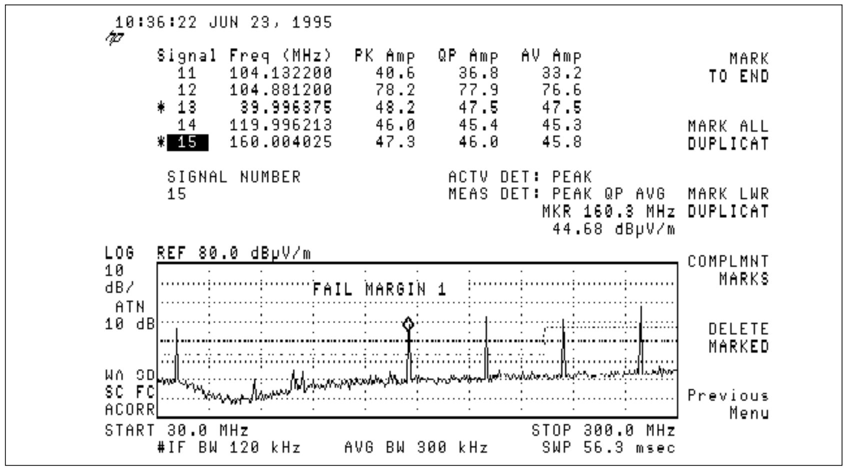


Figure 14. Radiated emissions measurement list.

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 [TEST], <More>, <EDIT LIST>, <Sort Signals>, <SORT BY QP AMP>.

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

Press [TEST], <More>, <SIG LIST ON>

Press <VIEW Δ> until VIEW QP Δ LIM 1 is indicated at the top of the right column. (See Figure 15)

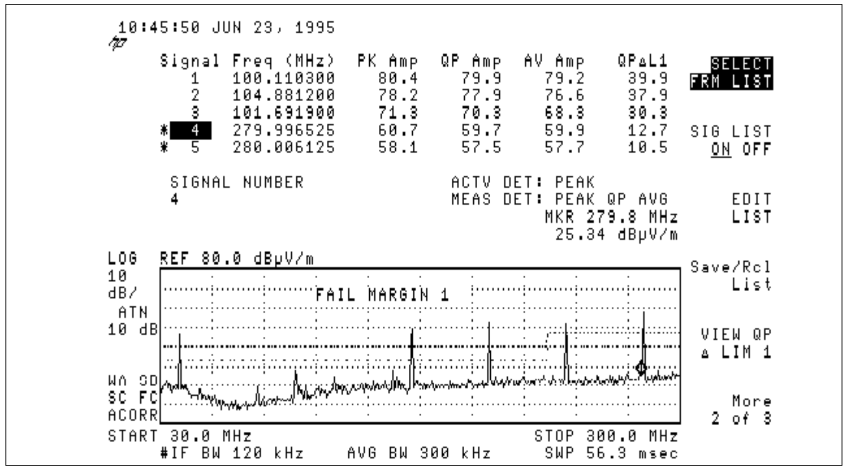


Figure 15. Measurements list compared to limit.

4.10 Evaluating Measurement Results

If all the values in the right hand 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 [TEST], <More>, <SIG LIST ON>

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

Press [DEMOD], <DEMOD ON>, <FM>.

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. 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 from 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 [TEST], <More>, <EDIT LIST>, <Delete Signals>, highlight the ambient signal to be deleted and press <DELETE MARKED>.

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 which is found during the test process. You can assemble a report using the [OUTPUT] functions. The contents of the report can include a list of signals, graphical representation of the signals, and up to two pages of text which can be generated using a common PC key board which connects to the rear of the EMC analyzer. To create the text, press the following:

[OUTPUT] and <EDIT ANNOTATN>

If unwanted text exists in the annotation area, press <CLEAR ANNOTATN>. Type in the desired text for your report. You may want to include the date, location of the testing, who performed the tests, product description, design engineer, and to which regulatory agency product is tested. Some general comments about the test results is usually helpful. After the text development is completed, press <EXIT EDIT>.

To define the report content press <Define Report>, then choose the items you would like to have in the report. Your report can include annotation, log graphics, linear graphics, instrument settings, and signal list information. Examples of log graph and linear graph are shown in Figures 16a and 16b on the following page.

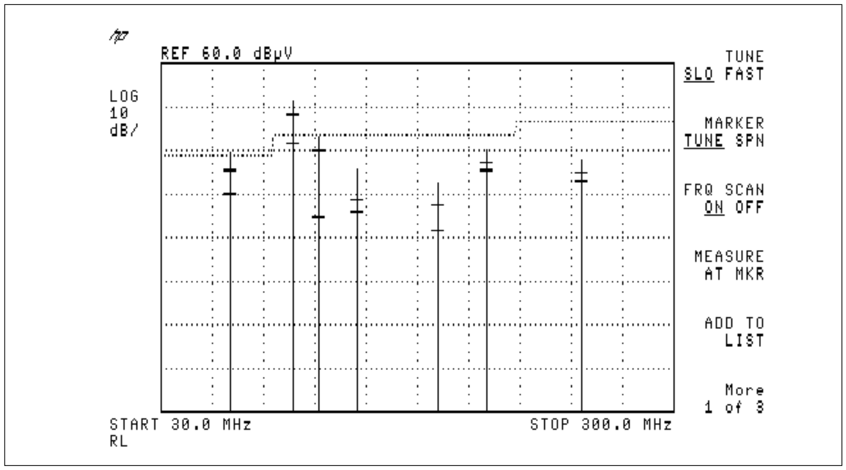


Figure 16a. Linear graph

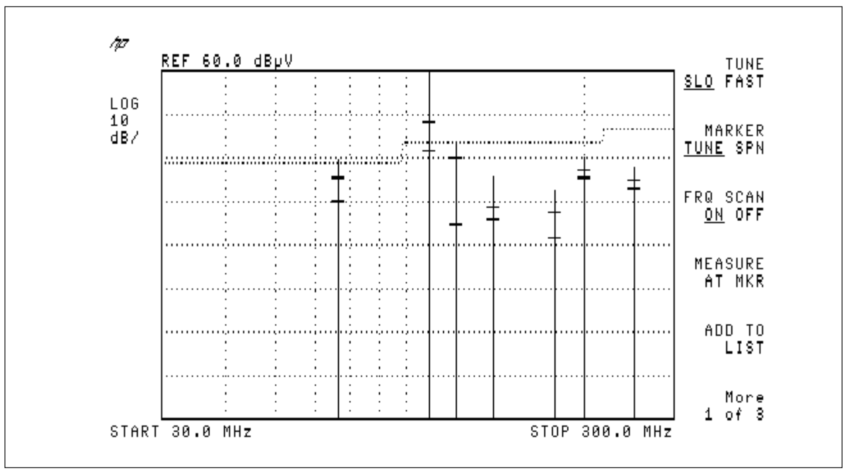


Figure 16b. Log graph

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 <OUTPUT REPORT>. All the items selected under report definition will be printed sequentially.

5.0 Problem Solving and Trouble Shooting

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 the Figure 17 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 on a RAM card.

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 on the RAM card and compare the results to the current measurement.

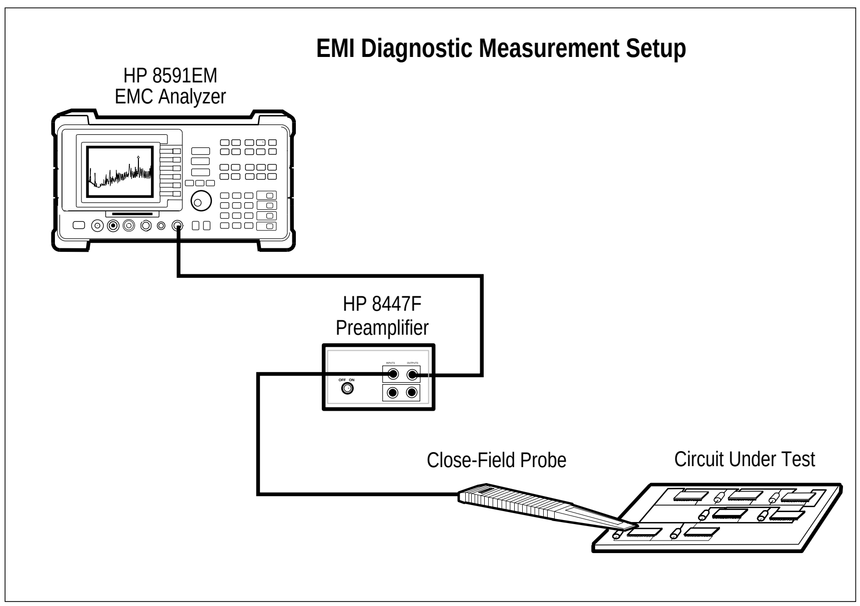


Figure 17. Diagnostics setup interconnection.

5.1 Diagnostics Testing Setup

As with emissions testing, the EMC analyzer must be setup to perform diagnostics testing. Corrections for the probe and amplifier must first be loaded into the EMC analyzer. The HP 11945A 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:

[SETUP], more, <Correctn factors>, <Antenna factors>, and <RECALL ANTENNA>.

Scroll down to the probe number which was installed and press <LOAD FILE>.

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

[SETUP], more, <Correctn factors>, <Other factors>, and <RECALL OTHER>.

Scroll down to the HP 8447F HI or LO depending on the probe used a press <LOAD FILE>.

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

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 a card. To store the display insert a formatted RAM card into the card reader and press the following:

[SAVE/RECALL], <Save Card>, <more>, <Trace ->CARD>, and <TRACE A>.

Select a register number (i.e., 5) and press [ENTER].

Figure 18 below is the trace saved into register 5 on the RAM card. The prefix name TRACE was generated using the “Change Prefix” functions.

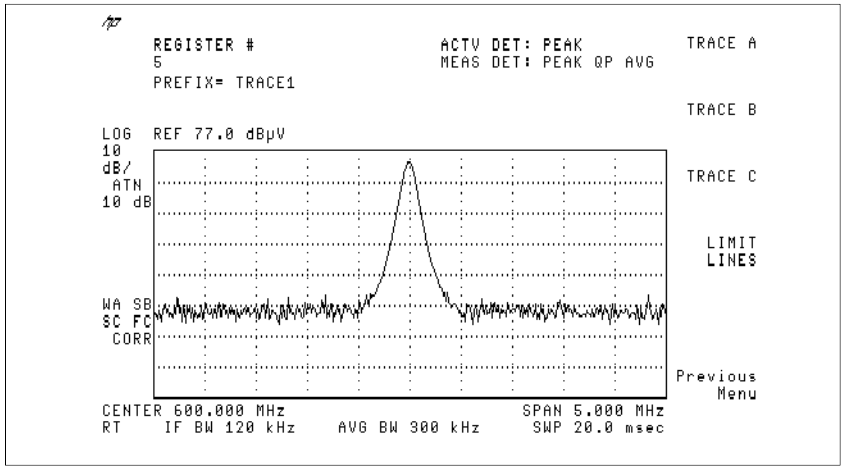


Figure 18. Isolated signal source display.

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

After the redesign, remeasure the results comparing the old trace before redesign to new trace by recalling the saved trace off the card. To recall the trace in register 5 press the following:

> [SAVE/RECALL], <Recall Card>, <more>, and <RECALL TRACE>.
>
> Scroll down to the trace you previously stored and press <LOAD FILE>.

The trace is recalled into the TRACE B area in the VIEW mode. The current trace is in TRACE A in the CLEAR WRITE mode. Figure 19 below shows the active trace and the recalled trace.

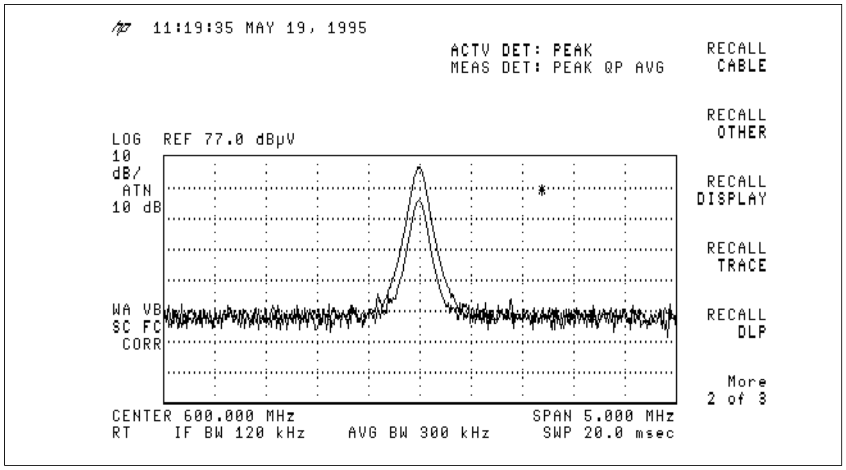


Figure 19. Emissions reduction comparison display.

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 is 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 is 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.

Appendix A
Line Impedance Stabilization Network (LISN)

A1.0 Purpose of a LISN

A line impedance stabilization network serve three purpose:

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

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

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

A1.1 LISN Operation

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

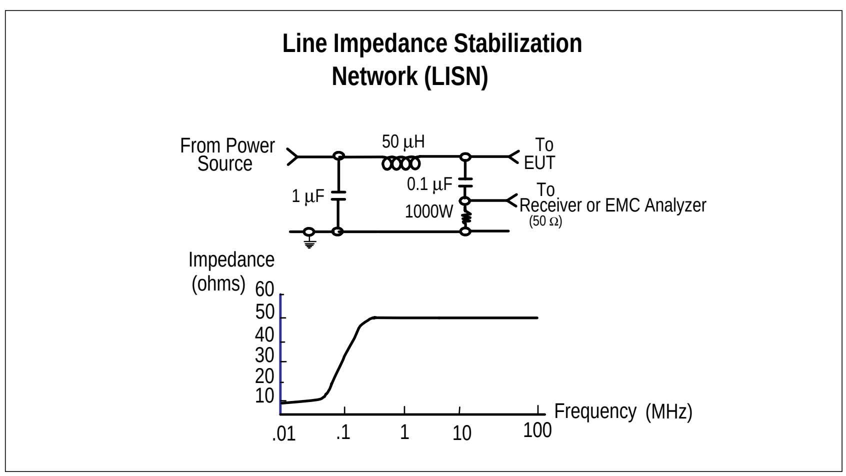


Figure A-1. Typical LISN circuit diagram.

The 1 μF in combination with the 50 μH inductor is the filter that isolates the mains from the EUT. The 50 μH inductor isolates the noise generated by the EUT from the mains. The 0.1 μF couples the noise generated by the EUT to the 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 above represents the impedance of the EUT port versus frequency.

A1.2 Types of LISNs

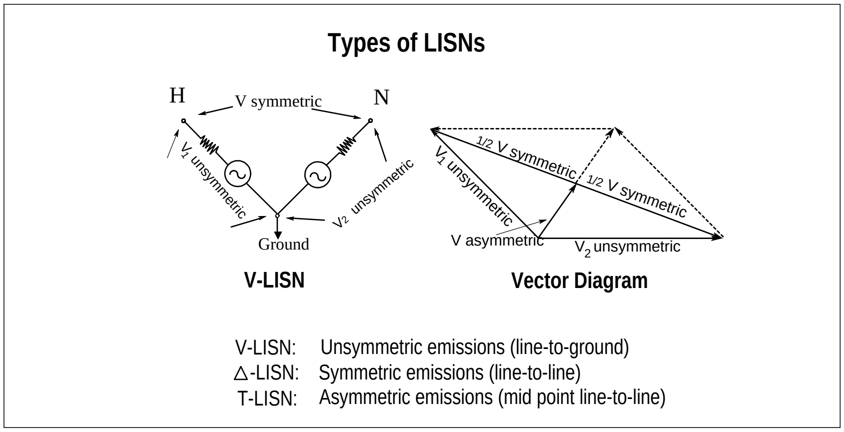


Figure A-2. Three different types of LISNs.

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 some other specialized types of LISNs. A delta LISN measures the line to line or symmetric emissions voltage. The T-LISN, sometimes used for telecommunications equipment, measures the 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 HP 11947A transient limiter incorporates a limiter, high pass filter, and an attenuator. It can withstand 10 kW for 10 μsec and has a frequency range of 9 kHz to 200 MHz. The high pass filter reduces the line frequencies coupled to the EMC analyzer.

Appendix B
Antenna Factors

B1.0 Field Strength Units

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

P_t = total power radiated from an isotropic radiator

P_D = the power density at a distance $\mathbf{r}$ from the isotropic radiator (far field).

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

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

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

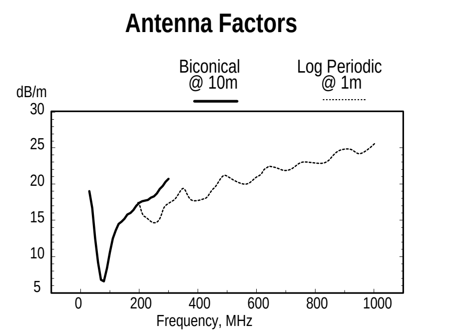
$E = (P_t \times 30)^{1/2} / \mathbf{r}$ (V/m)

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

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

B1.1 Antenna Factors

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



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

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

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

Figure B-1. Typical antenna factor shapes.

B1.2 Types of Antennas Used for Commercial Radiated Measurements

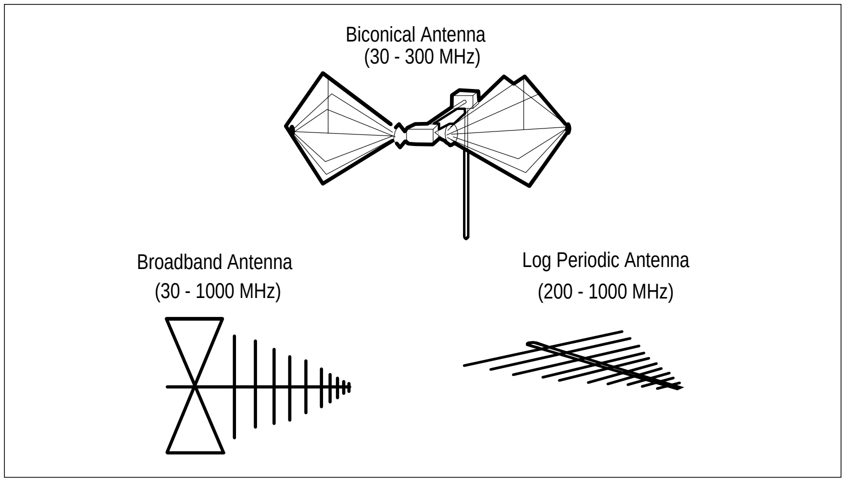


Figure B-2. Antennas used in EMI emissions measurements.

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

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

Appendix C

Basic Electrical Relationships

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

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

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:

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

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

$$\textbf{dBmV} = 107 + P_{dBm}$$

This is true for an impedance of 50Ω

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

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

Appendix D
Detectors Used in EMI Measurements—Peak, Quasi-Peak, and Average

D1.0 Peak Detector

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

D1.2 Peak Detector Operation

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

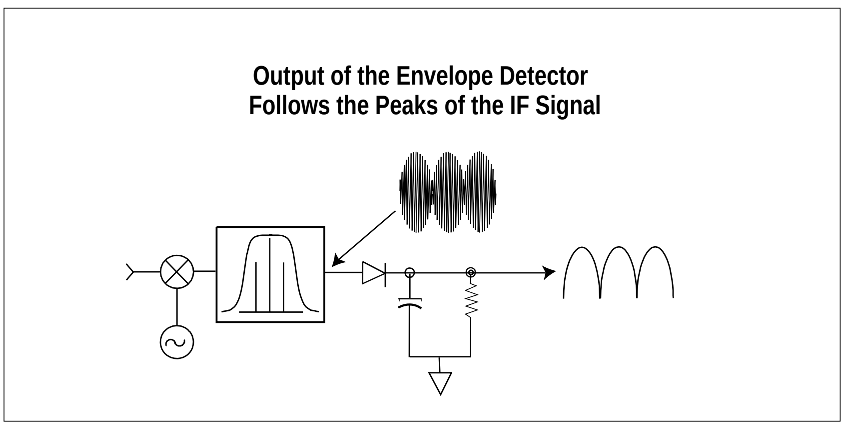


Figure D-1. Peak detector diagram.

D2.0 Quasi-Peak Detector

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

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

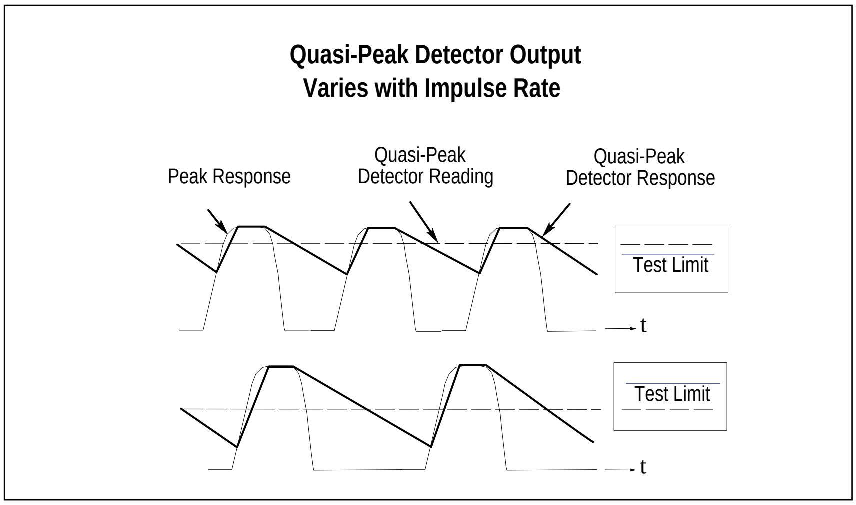


Figure D-2. Quasi-peak detector response diagram.

D2.1 Quasi-Peak Detector Operation

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

D3.0 Average Detector

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

D3.1 Average Detector Operation

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

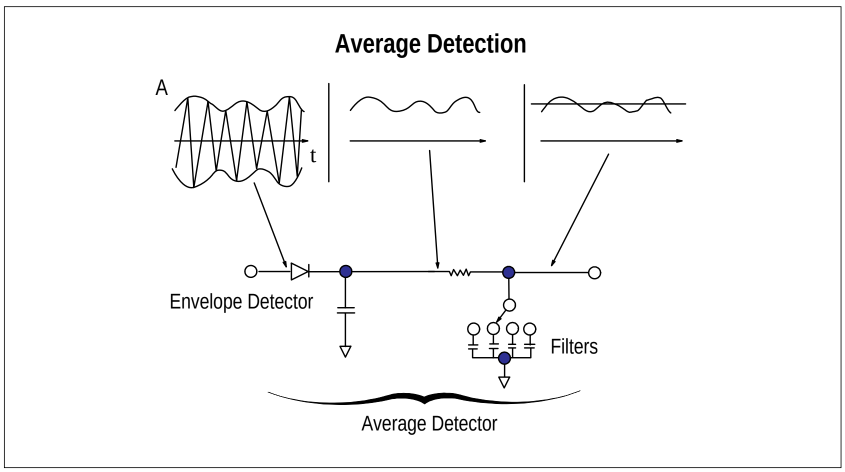


Figure D-3. Average detection response diagram.

Appendix E
EMC Regulatory Agencies

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

IEC
CISPR
Sales Department of the Central Office of the IEC
PO Box 131
3, Rue de Verembe
1121 Geneva 20, Switzerland

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

Canadians 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
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
Cometato 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

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: + 48 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 49 00
Fax: 212 302 12 86

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 in inoperative. Atmospherics, interference from other sources, and circuit noise, or other interference generated within the measuring set compose the ambient level.

Amplitude Modulation

1. In a signal transmission system, the process, or the result of the process, where the amplitude of one electrical quantity is varied in accordance with some selected characteristic of a second quantity, which need not be electrical in nature.

2. The process by which the amplitude of a carrier wave is varied following a specified law.

Anechoic Chamber

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

Antenna (Aerial)

1. A means for radiated or receiving radio waves.

2. A transducer which either emits radio frequency power into space from a signal source or intercepts an arriving electromagnetic field, converting it into an electrical signal.

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

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

Antenna Terminal Conducted Interference
Any undesired voltage or current generated within a receiver, transmitter, or their associated equipment appearing at the antenna terminals.

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

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

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

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

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

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

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

Dipole
1. An antenna consisting of a straight conductor usually not more than a half-wavelength long, divided at its electrical center for connection to a transmission line.

2. Any one of a class of antennas producing a radiation pattern approximating that of an elementary electric dipole.

Electromagnetic Compatibility (EMC)

1. The capability of electronic equipment of systems to be operated within a defined margins in of safety in the intended operational environment at designed levels of efficiency without degradation due to interference.

2. EMC is the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances into that environment or into other equipment.

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

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

Emission
Electromagnetic energy propagated from a source by radiation or conduction.

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

Ground Plane
1. A conducting surface of plate used as a common reference point for circuit returns and electric or signal potentials.

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

Immunity

1. The property of a receiver or any other equipment or system enabling it to reject a radio disturbance.

2. The ability of electronic equipment to with stand radiated electromagnetic fields without producing undesirable responses.

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

Isotropic
Isotropic means having properties of equal values in all directions.

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

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

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

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

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

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

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

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

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

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

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

For more information about Hewlett-Packard test and measurement products, applications, services, and for a current sales office listing, visit our web site, http://www.hp.com/go/tmdir. You can also contact one of the following centers and ask for a test and measurement sales representative.

United States:
Hewlett-Packard Company
Test and Measurement Call Center
P.O. Box 4026
Englewood, CO 80155-4026
1 800 452 4844

Canada:
Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
L4W 5G1
(905) 206 4725

Europe:
Hewlett-Packard
European Marketing Centre
P.O. Box 999
1180 AZ Amstelveen
The Netherlands
(31 20) 547 9900

Japan:
Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192, Japan
Tel: (81-426) 56-7832
Fax: (81-426) 56-7840

Latin America:
Hewlett-Packard
Latin American Region Headquarters
5200 Blue Lagoon Drive, 9th Floor
Miami, Florida 33126, U.S.A.
(305) 267 4245/4220

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130, Australia
1 800 629 485

Asia Pacific:
Hewlett-Packard Asia Pacific Ltd.
17-21/F Shell Tower, Times Square,
1 Matheson Street, Causeway Bay,
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