HEWLETT® PACKARD

Making Radiated and Conducted Compliance Measurements with EMI Receivers

Application Note 1302

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1.0 Introduction to compliance measurements

Note: In this application note, detailed measurement procedures are provided for HP 8542E and 8546A EMI receivers.

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

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

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

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

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

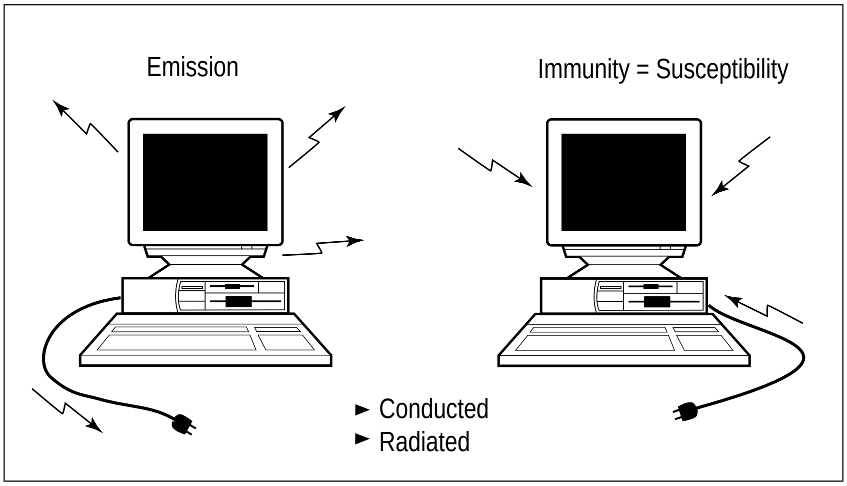


Figure 1. Two types of EMC measurements.

2.0 The compliance measurements process

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

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

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

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

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

International regulations summary (Emissions)

CISPR	FCC	EN's	Description
11	Part 18	EN 55011	Industrial, scientific and medical
12	(SAE)		automotives
13	Part 15	EN 55013	Broadcast receivers
14		EN 55014	Household appliances/tools
15		EN 55015	Fluorescent lights/luminaries
16			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

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

Table 1b. Major European requirements.

European norms

EN55011 (CISPR 11)

Industrial, scientific and medical products.

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

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

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

EN55014 (CISPR 14)

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

	DOS disk 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 and telecommunications equipment.)

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

FCC
(Federal Communications Commission)

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

Table 1c. FCC regulations

Federal Communications Commission

FCC Part 15

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

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

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

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

3.0 Compliance EMI receiver requirements

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

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

- Amplitude accuracy:
  Nominally a ±2 dB absolute amplitude accuracy is required
- Specified bandwidths:
  CISPR specifies the following bandwidths (16 dB):

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

1. Comite International Special des Perturbations Radioelectriques

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

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

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

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

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

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

The HP 8542E and 8546A were independently certified to meet these CISPR-16 requirements by the German BZT[1]. These receivers also contain autoranging capabilities and overload detection in all frequency ranges and modes of operation.

1. Bundesamt für Zulassungen der Telekommunikution, the german appeals office for telecommunications

3.1 Requirements above 1 GHz:

FCC regulations and proposed CISPR regulations require a 1 MHz bandwidth for measurements above 1 GHz. The HP 8542E and 8546A receivers also meet these requirements.

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

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

4.0 Preparing conducted emissions measurements

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

4.1 Conducted test setup

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

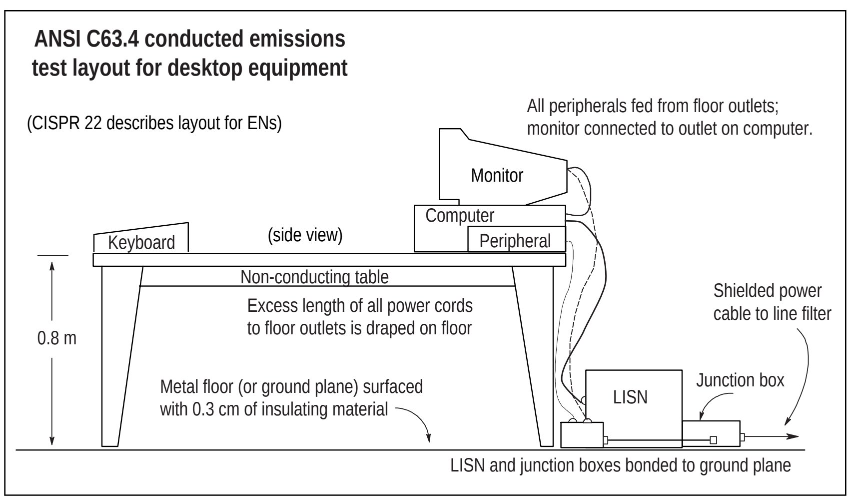


Figure 2: Side view of conducted test setup. The LISN output connects to the receiver.

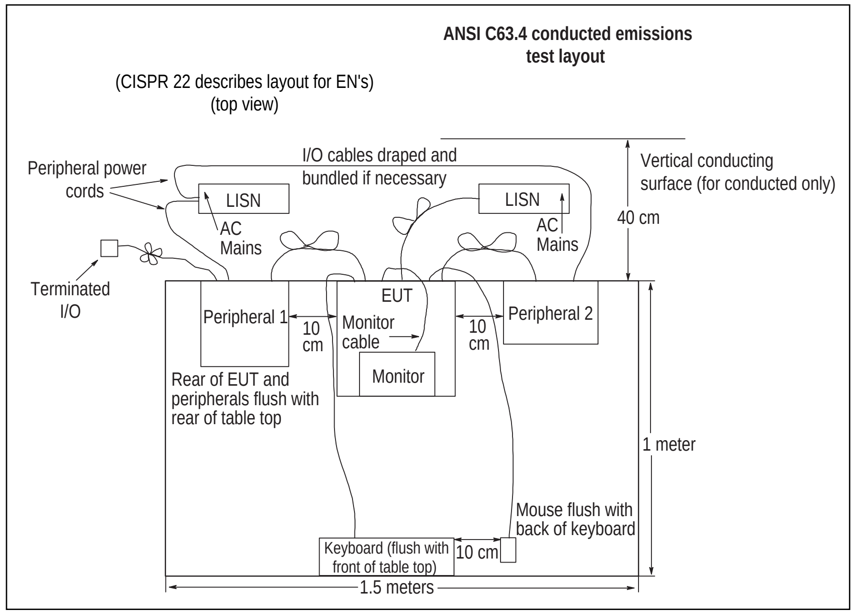


Figure 3: Top view of conducted test setup. The LISN output connects to the receiver.

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

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

Note: The setup does not include a separate transient limiter for transient protection. The HP 8542E and 8546A have built-in transient limiters.

4.2 Configuring the receiver

Note: The following sequence of steps for making a compliant measurement with the EMI receiver assumes that the measurement setup and measuring receiver are compliant with the applicable standard.

1. Disconnect the input to the receiver. Power up the EMI receiver.

2. Set up the correct frequency range by pressing [SETUP], <150 kHz - 30 MHz>. The HP 8542E or 8546A automatically selects the correct CISPR bandwidth.

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

Press [SETUP], <More>, <Limit Lines>, <RECALL LIMITS>.

Scroll down and highlight the required limit line (for example, EN022_BC is the conducted limit for class B products for EN55022). Press <LOAD FILE>. (See Figure 4). The EN022_BC contains both the EN55022 quasi-peak and average limits.

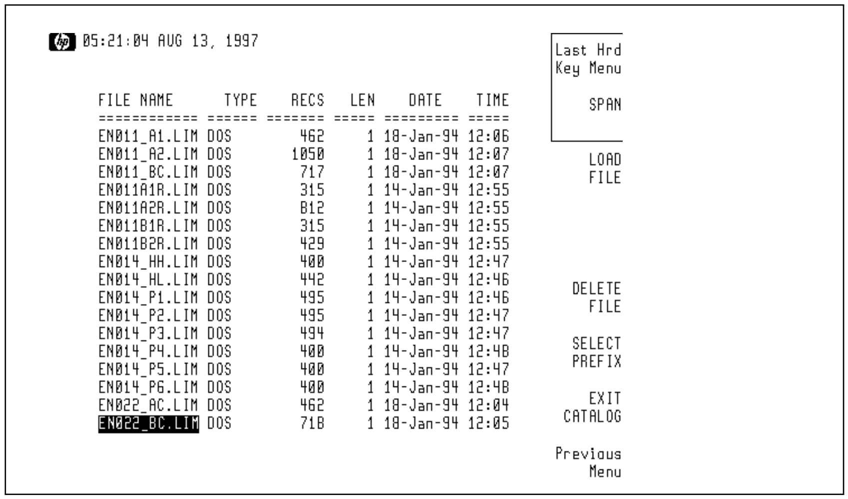


Figure 4: Loading limit lines for an EN55022 conducted test.

3. Next, correct the LISN by pressing the following keys:

[SETUP], <More>, <Correctn factors>, <Antenna Factors>, <RECALL ANTENNA>.

Scroll down to LISN or LISN10A, depending on the LISN you are using. These files can be edited for your custom use.

Press <LOAD FILE>. (See Figure 5).

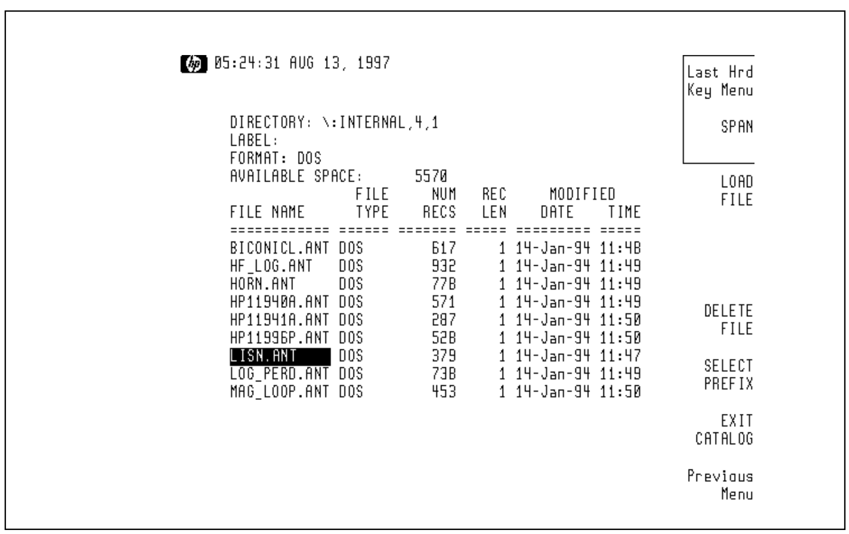


Figure 5: Loading correction factors for a LISN.

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

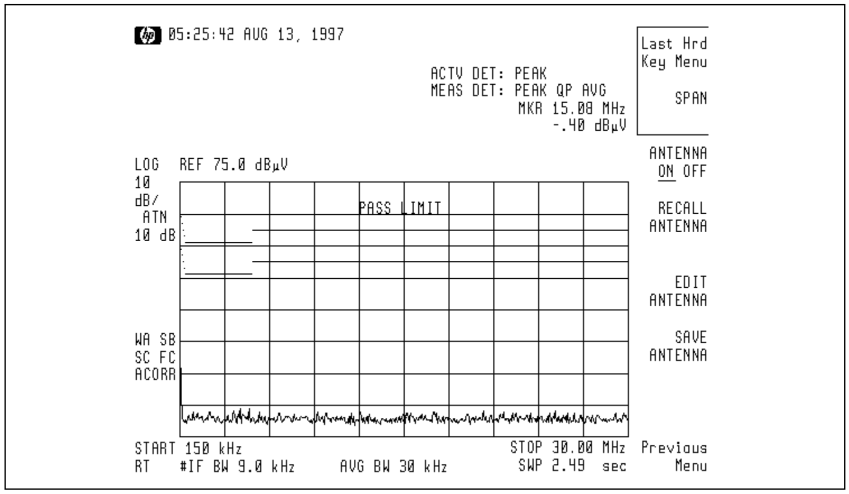


Figure 6: Display corrected for a LISN and limit lines on (no input connected to the receiver). The top limit is the quasi-peak limit and the bottom limit is the average limit.

4.3 Performing conducted emissions measurements

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

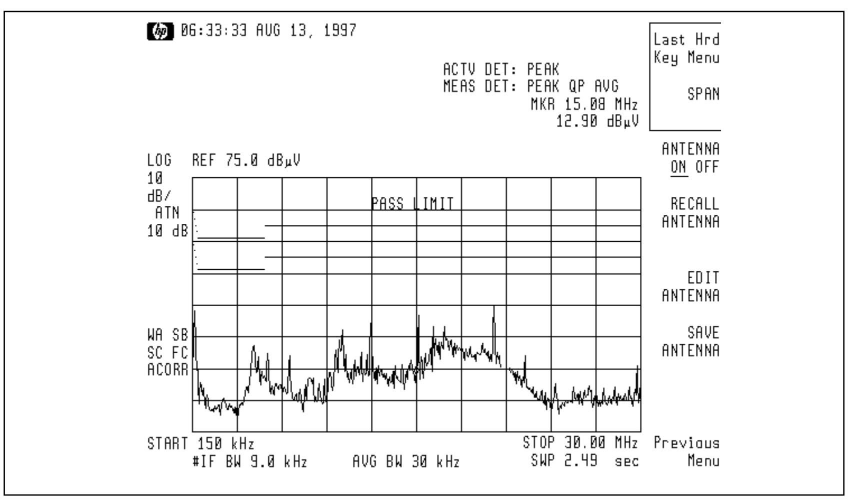


Figure 7: A conducted test in an ambient environment.

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

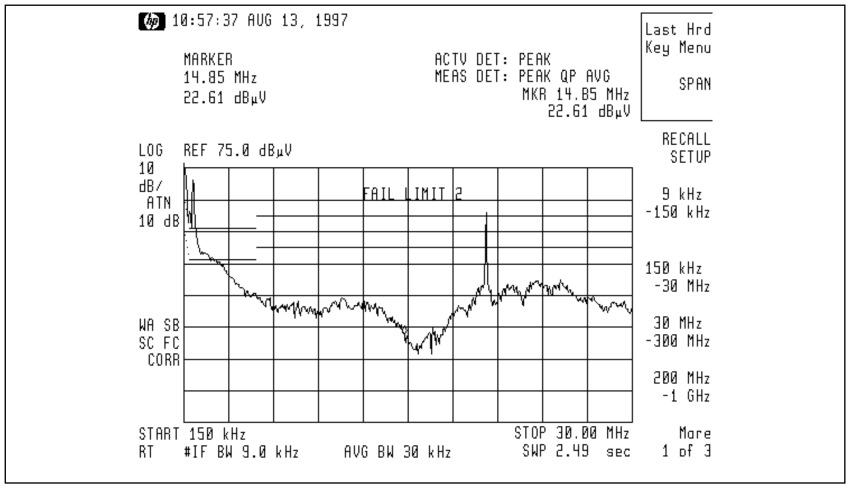


Figure 8: Conducted failure

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>

In Figure 9, the display is in a log frequency format. Since log frequency sweep expands the lower decades, the signals at the lower frequencies are more clearly shown than in the linear frequency mode.

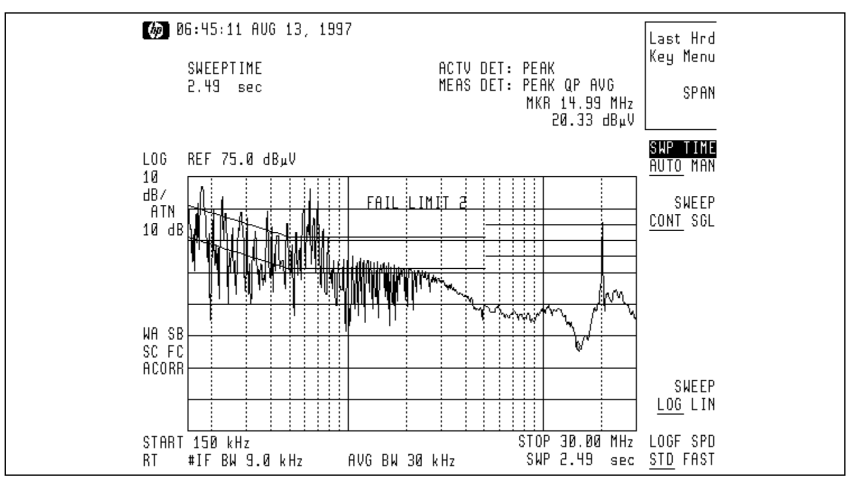


Figure 9: Log sweep for conducted test

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.

Before measuring, make sure you have enabled the correct detectors. Press [SETUP], <More>, <Inst Setup>, <Measure Detector>

Press <Measure Detector> until the correct detectors are underlined; i.e., peak (PK), quasi-peak (QP) and Average (AVG).

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

1. Press [CTRL] in the Windows section then use <ZONE CENTER> and <ZONE SPAN> to zoom in on the signals of interest in the active trace. (See Figure 7).

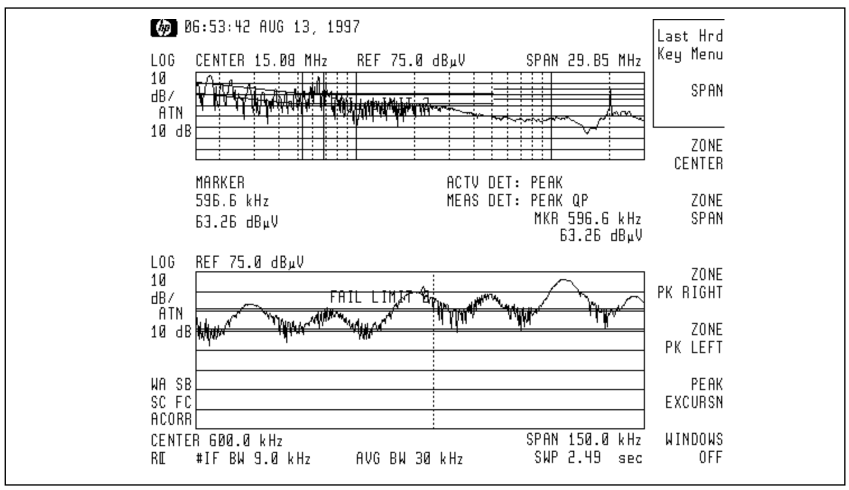


Figure 10: “Windows” function, zooming in on signals

2. Press [TEST]

3. Use the knob or the up/down keys to place the marker on a signal of interest.

4. Press <MEASURE AT MKR>. After the measurement is completed, the signal frequency and amplitude will appear in the box above the display.

5. Press <ADD TO LIST> to add your signal to the receiver internal signal list.

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

The HP 8542E and 8546A can automatically measure all signals above the limit or margin with the “automeasure” function. Press [TEST], <More>, <More>, <AUTOMEASURE>. These signals will be stored in the signal list.

At this point, all the measured signal values are in the internal list of the EMI receiver. To view the list and determine which signal’s quasi-peak levels are above the limit:

Press [TEST]<More> <SIGNAL LIST ON>

Press <VIEW Δ > until QP Δ limit 1 is shown. (See Figure 11).

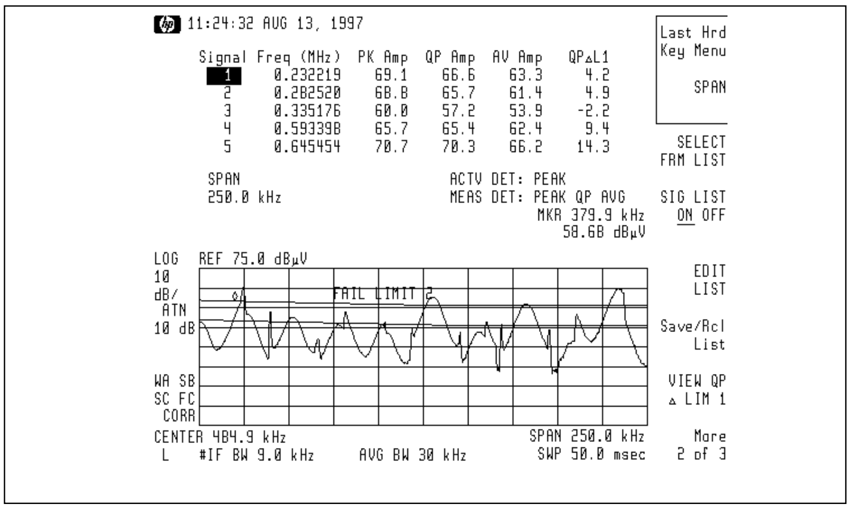


Figure 11: Signal list

If there are no quasi-peak values above the quasi-peak limit (positive values), and average values above the average limit, then your product passes, or if there are no quasi-peak values above the average limit, then your product passes.

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

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

5.0 Preparing for radiated emissions measurements

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

5.1 Open site requirements

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

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

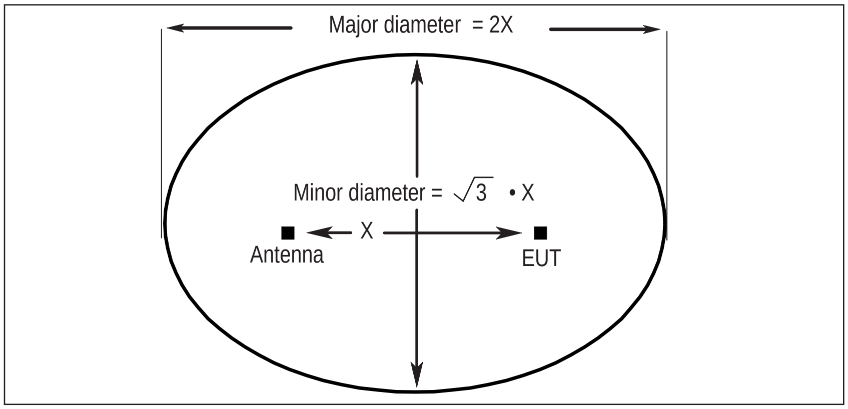


Figure 12: The CISPR ellipse

- The OATS must pass a "normalized site attenuation" test,

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

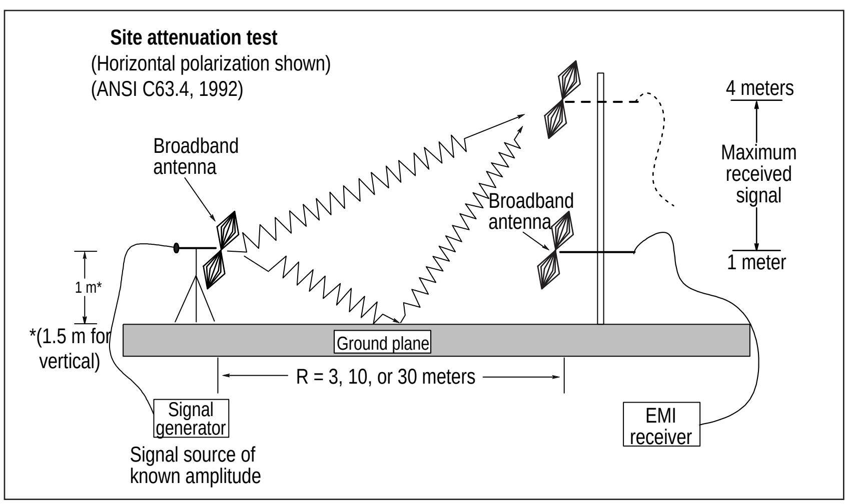


Figure 13: NSA procedure schematic, horizontal polarization

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

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

5.2 Radiated emissions test setup

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

1. Arrange the antenna, EUT and EMI receiver as shown in Figure 14. Separate the antenna and the EUT by 3 meters (10 meters if the regulation calls it out). CISPR and ANSI require your EUT to be in worst case mode of operation (i.e. attached cables, monitor, scrolling Hs across the monitor, etc.)

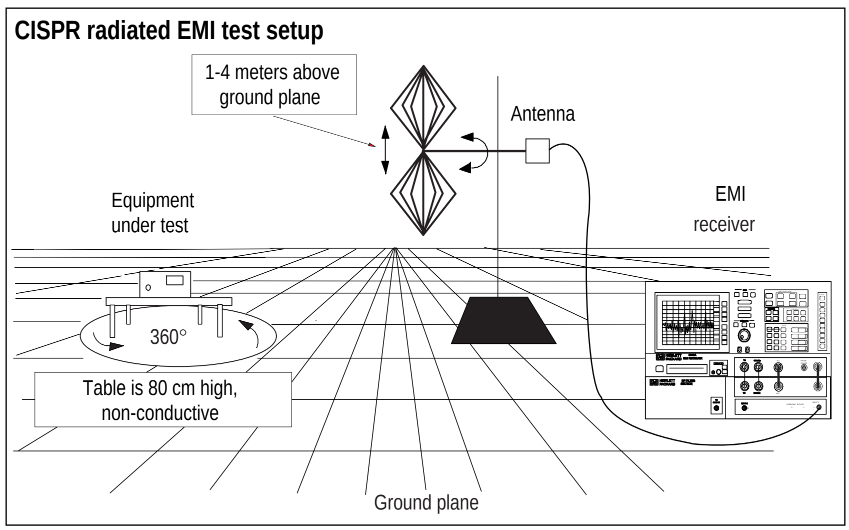


Figure 14: Radiated test setup.

2. Use Table 1 (page 4) to determine the regulation that your product must be tested to.

3. Set up the EMI receiver for the correct span, antenna correction factors, and limit line with a margin. In this case, we are testing to the FCC part 15, class B 3 meter limit. Load in the appropriate limit line using the following steps:

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

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

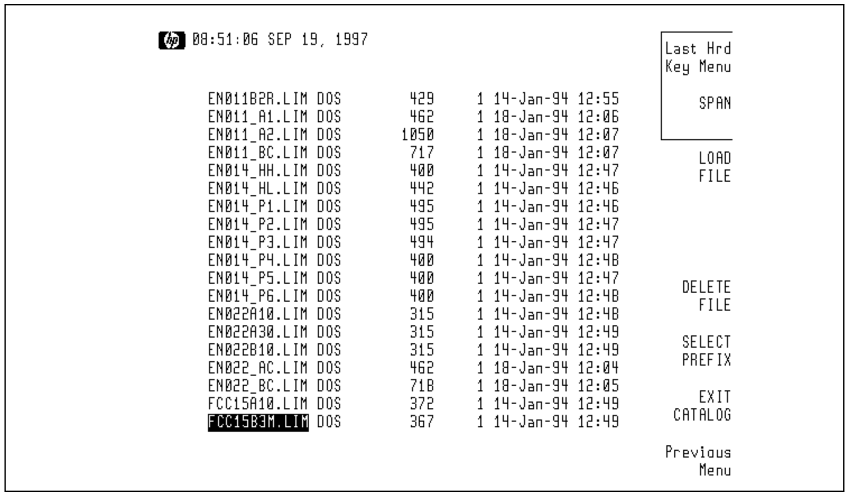


Figure 15: Loading FCC 3-meter class B limit.

4. Press <LOAD FILE>

5. Load the appropriate antenna correction factors. The HP 8542E/8546A series have two preset radiated emissions test bands, 30 MHz to 300 MHz and 300 MHz to 1 GHz. The 30 MHz to 300 MHz band uses a biconical antenna and the 300 MHz to 1 GHz band uses a log periodic antenna. There is also a broadband antenna (HP 11966P), which covers 30 MHz to 1 GHz.

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

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

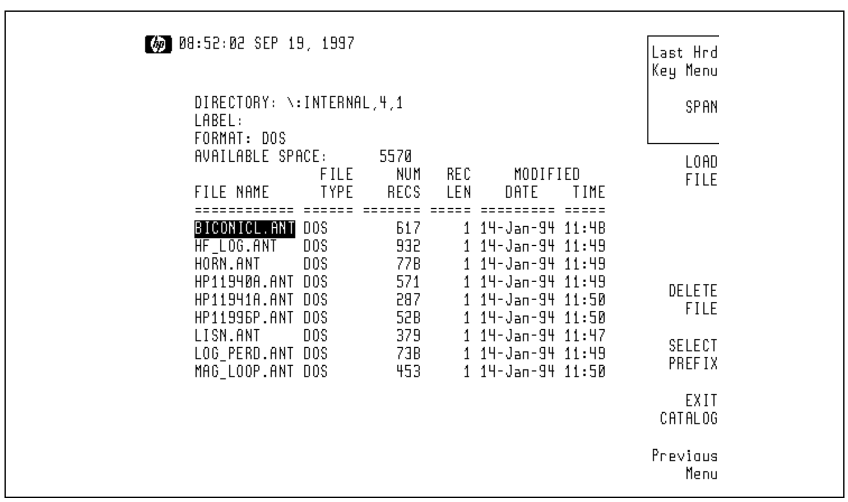


Figure 16: Loading correction factors for a biconical antenna.

Press <LOAD FILE>.

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

5.3 Measuring radiated emissions

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

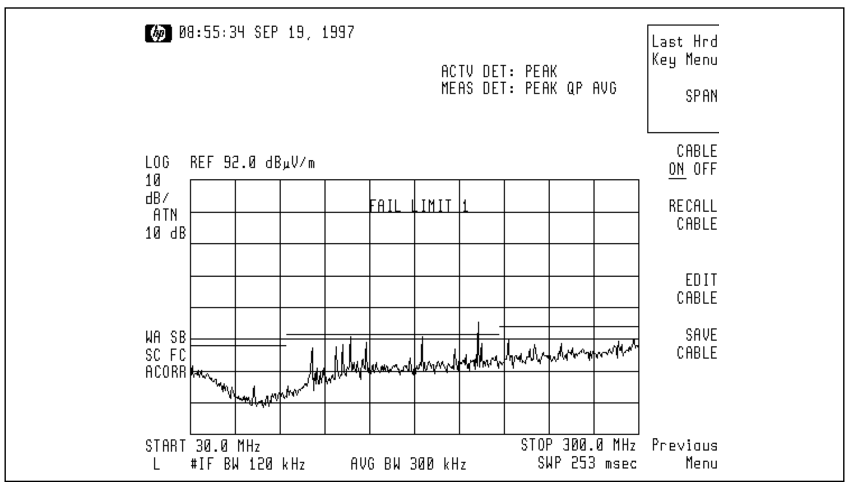


Figure 17: An ambient environment for radiated emissions. Ambients can often be above your limit line.

5.4 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 [TRACE], <MAX HOLD A>. (This function captures most signals, including low PRF signals)

2. Turn on the "WINDOW" function on by pressing [CTRL] 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 (above the margin if it was initiated). To enable a margin on the limit line, perform the following:

Press [SETUP], <More>,<Limit Lines>, <Limit 1>, <Margin 1 ON>, then enter your margin, which typically is 6 dB. Margins are useful when considering the entire measurement uncertainty of your test setup (including antennas, cables, preamplifiers and the receiver.)

Press [TEST], <More>, <More>, <AUTOMEASURE> to perform the automeasure.

At this point, the EMI receiver is performing a peak, quasi-peak and average measurement on all signals above the limit line or margin (if these detectors were enabled). The signals measured are the ambients (signals produced by other sources) with the 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 broad trace are measured. Press [CTRL] under the WINDOW area to view the menu containing <ZONE CENTER>. Press <ZONE CENTER> and use the knob to move the zone marker to the next group of signals.

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

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

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

2. At each 45-degree step, note the amplitude of the largest signals. With a printer connected to the I/O port, press [COPY] to obtain a screen dump at each step.

3. On each screen dump, mark the position of the EUT.

After all the screen dumps 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, you may find worst-case for 100 MHz emissions at 90-degrees and at 270 degrees for 200 MHz. In this case, the emissions tests must be performed at both positions. If you are not sure whether the signal you are looking at is an ambient or EUT signal, switch the EUT off. An ambient signal will not change. Worst case emissions must be found for both horizontal and vertical polarizations.

5.6 Ambient plus EUT measurements

With the EUT turned on and oriented to the worst case position, perform automated tests again as follows:

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 “automeasure” function to automatically measure the signals above the limit line (or above the margin if it was initiated): Press [TEST], <More>, <More>, <AUTOMEASURE>.

To capture the signals over the rest of the band, repeat the signal measurement process (5.5) to capture all the signals above the limit. At this point, the EMI receiver is performing a peak, quasi-peak and average on all signals above the limit line or margin 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. The signals measured are the ambients plus 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 (the ambient signals). To remove the ambient signals, perform the following:

Press [TEST], <More>, <EDIT LIST>, <Signal Marking>, <Selectv Mark>, <MARK ALL DUPLICAT>, and <DELETE MARKED>.

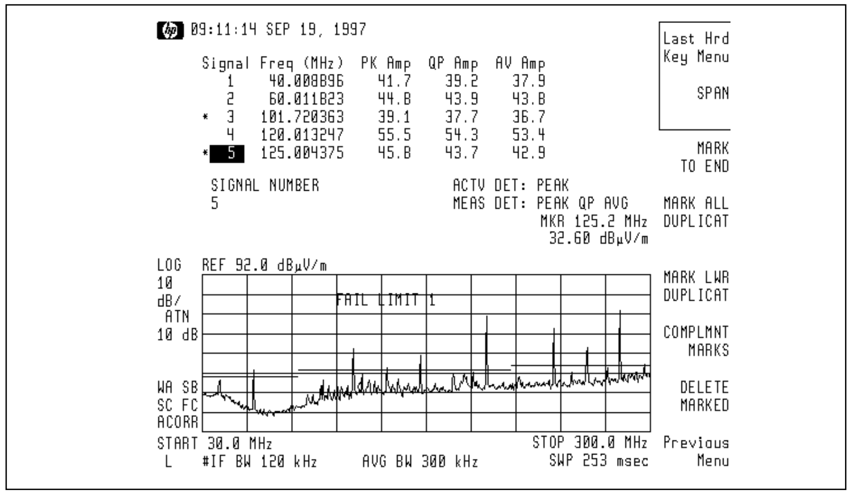


Figure 18: Marking and deleting ambients from your list

At this point, most of the ambient signals have been deleted from your list. Some ambients may have been present for one of the automatic measurements but not for the other measurement. It would not have duplicate signals and would not be deleted. The signals in the list are the peak, quasi-peak and average values of the EUT emissions and remaining ambient signals.

Next, find signals that are above the limit. To do this, 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 on the column that 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 19).

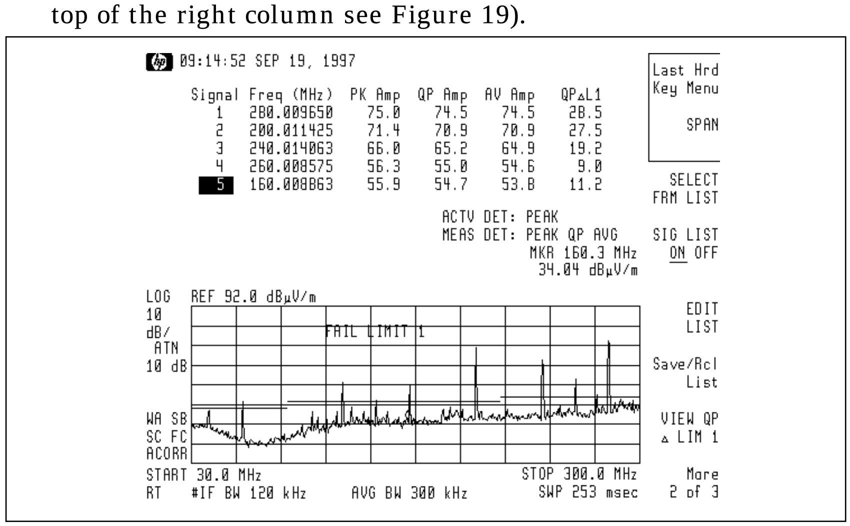


Figure 19: Final EUT signal list

5.7 Evaluating measurement results

If all the values in the right hand column are negative, then the product emissions are below the limit and your product passes the radiated emissions requirements. If some of the values are positive, then the quasi-peak measurements are above the QP limit and the product fails the radiated emissions measurements. To be sure that a signal is not ambient, it should be remeasured and the demodulation function used to listen to the signal. AM/FM demodulation is a good tool for determining 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 [SELECT] in the DEMOD section

Press<DEMOD ON>, <FM>

Adjust the volume to listen to the signal. If the signal is a local AM, FM, TV or cellular phone transmission, 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. In this case using the demodulation function may be the preferred method of identifying ambients.

If you have determined that a signal is an ambient, then you need to delete the signal.

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

After the ambient signals have been deleted from the list, a report can be developed.

6.0 Report development

The end result of 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 [OUTPUT] functions. The report can include a list of signals a graphical representation of the signals and up to two pages of text, which can be generated using a common PC keyboard that connects to the rear of the EMI receiver.

6.1 Using the HP 85878A EMI report generator software

The HP 85878A report generator software comes with each HP 8546A or 8542E EMI receiver purchase. The HP 85878A can be used to capture data from your receiver and automatically generate reports.

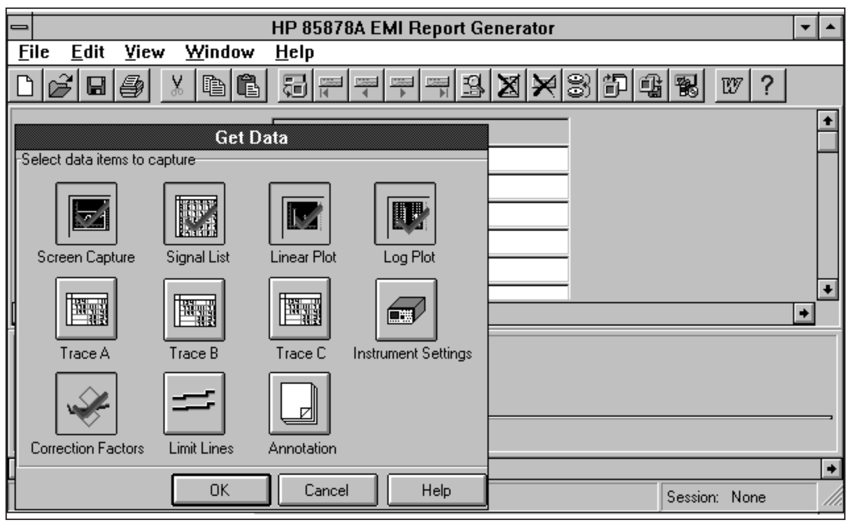


Figure 20: Capture the data you want with a few mouse clicks using the HP 85878A.

The HP 85878A uses object linking and embedding (OLE) technology, so you can easily drag and drop your captured data in Microsoft Word®. Each data session you perform is stored in a database for search and retrieval.

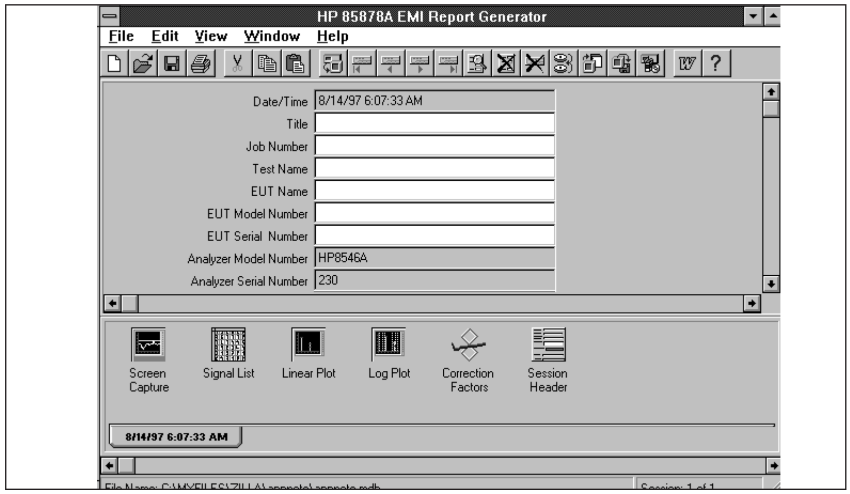


Figure 21: Data icons can be dragged and dropped to Microsoft Word.

Using Microsoft Word and macros, you can automatically generate large reports. Your data icons are "bookmarked" and automatically inserted into your report.

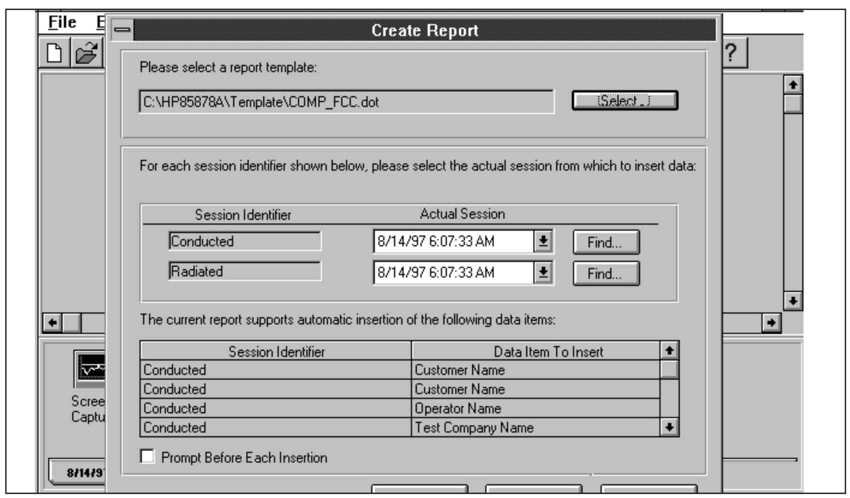


Figure 22: Custom report templates allow fast generation of reports to compliance authorities and for engineering archives.

7.0 Using software to improve radiated EMI test throughput

Software packages that automatically control the movements of towers and turntables, capture emissions and find worst-case emissions are available. In addition to generating compatible reports, the HP 85876B commercial radiated EMI software also performs these functions.

For example, the HP 85876B has an icon set that can be used to set up your equipment path and automatically import your correction factors.

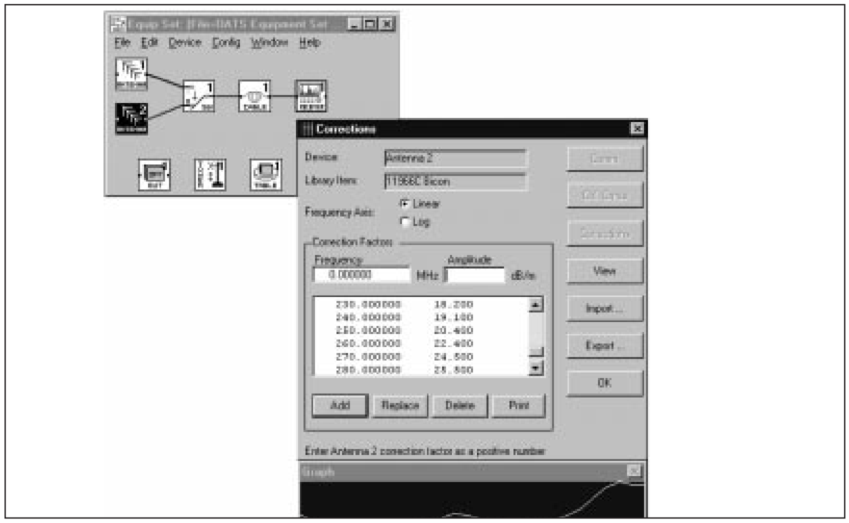


Figure 24: The HP 85876B can set up your equipment and import correction factors to correct for your measurement path.

Predefined, editable test procedures enable you to automate your test process.

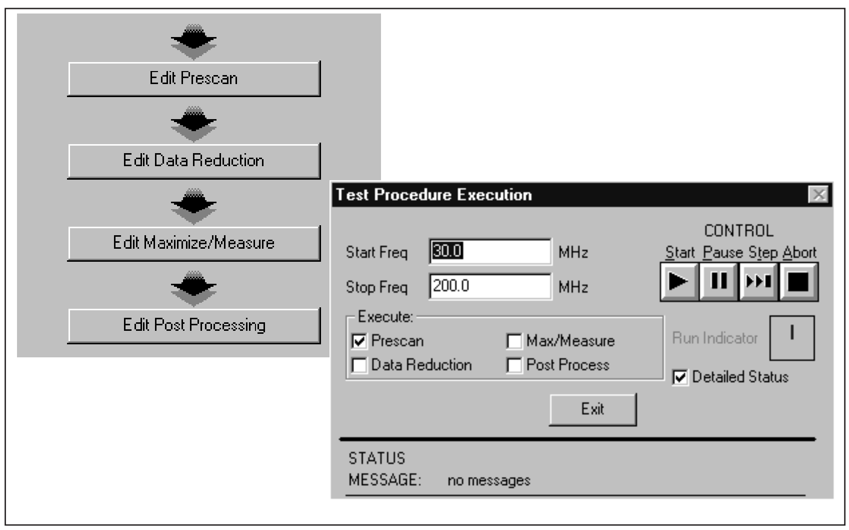


Figure 25: Test procedures and control.

The software enables you to control your receiver and add additional signals to your signal list with a marker “add to active list function.

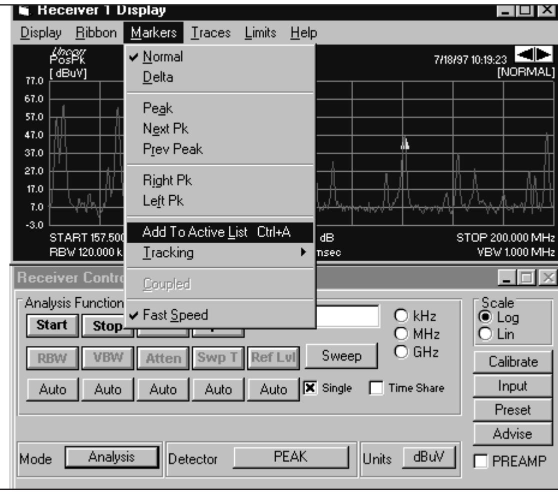


Figure 26: Software receiver control

Other signal maximization and control tools assist you in finding your worst case emissions. The software enhances repeatability, and improves throughput.

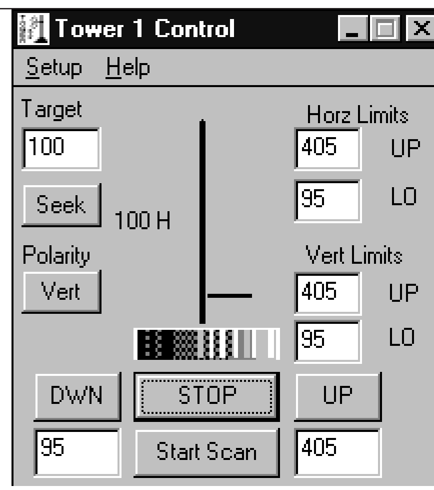


Figure 27: Tower control panel

Below is a polar plot and a height/azimuth plot of a measured signal. The near-omnidirectional radiation pattern of the signal could signify that it is an ambient.

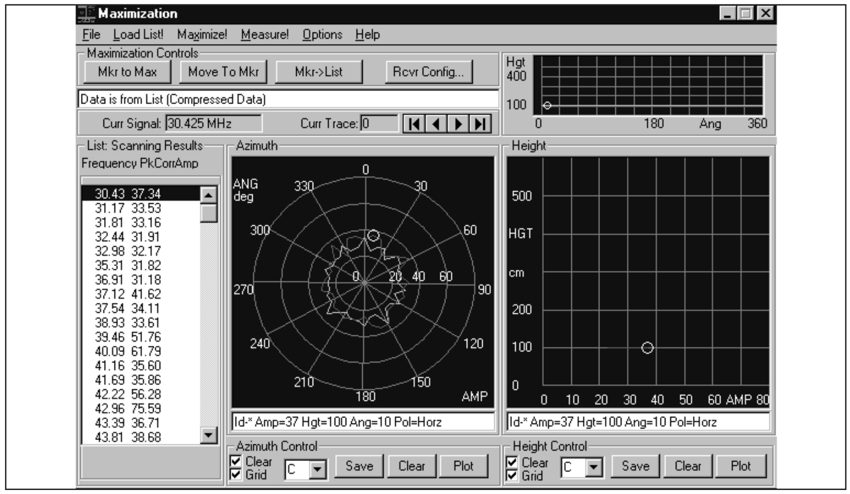


Figure 28: Maximization and graphical tools assist you in performing your final measurement.

The HP 85876B allows you to save files as *.rtf (rich text files) for easy import into popular word processing programs. Graphics can be saved as *.wmf (Windows Metafile) for quick pasting into many Windows-based applications.

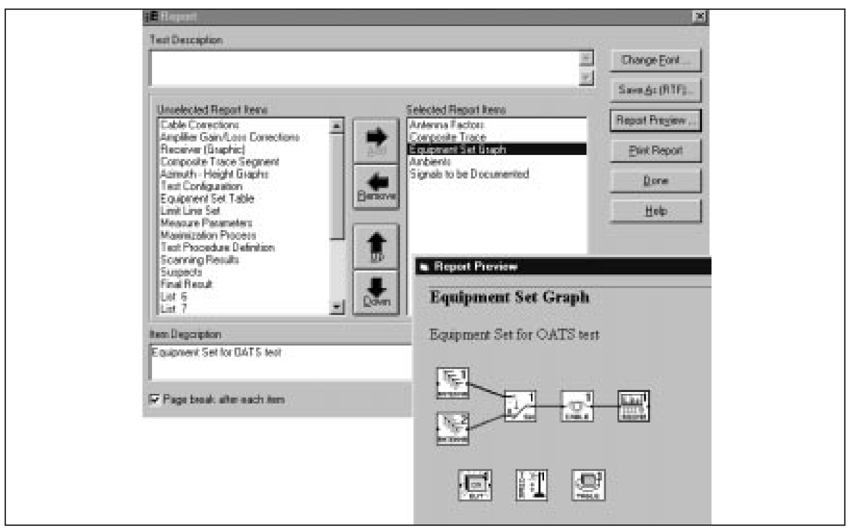


Figure 29: HP 85876B reporting capabilities

Appendix A

Line impedance stabilization networks

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.

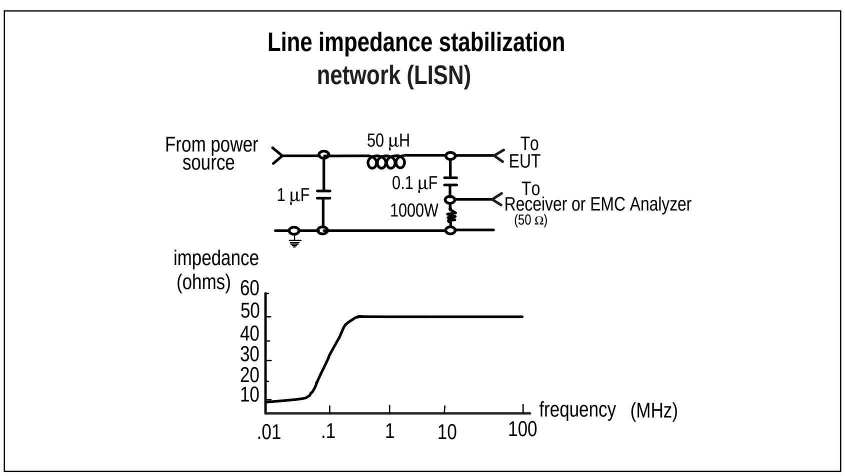


Figure A-1. Typical LISN circuit diagram.

The 1 µF capacitor in combination with the 50 µH inductor is the filter that isolates the mains from the EUT. The 50 µH inductor isolates the noise generated by the EUT from the mains. The 0.1 µF 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

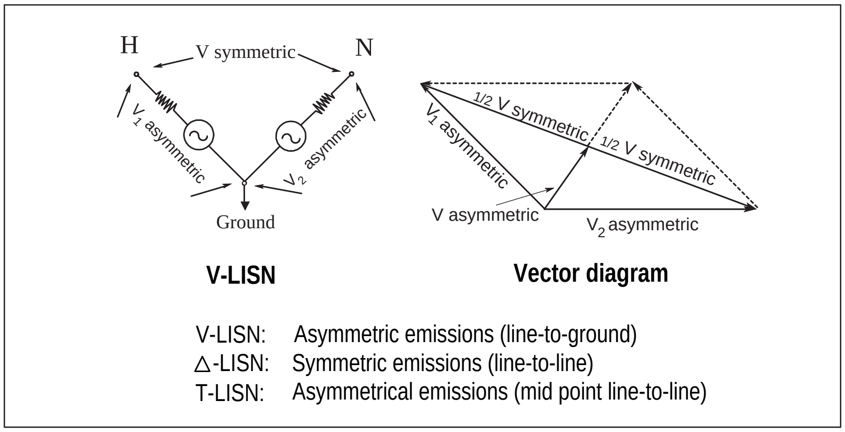


Figure A-2. Three different types of LISNs.

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

A2.0 Transient limiter operation

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

The 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 **r** from the isotropic radiator (far field).

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

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

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

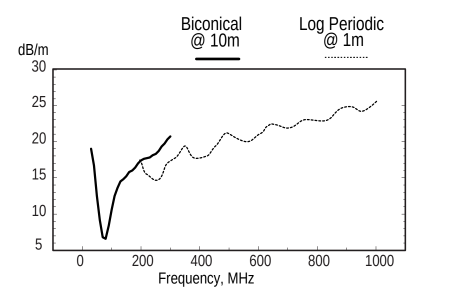
$E = (P_t \times 30)^{1/2} / \mathbf{r}$ (V/m)

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

*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

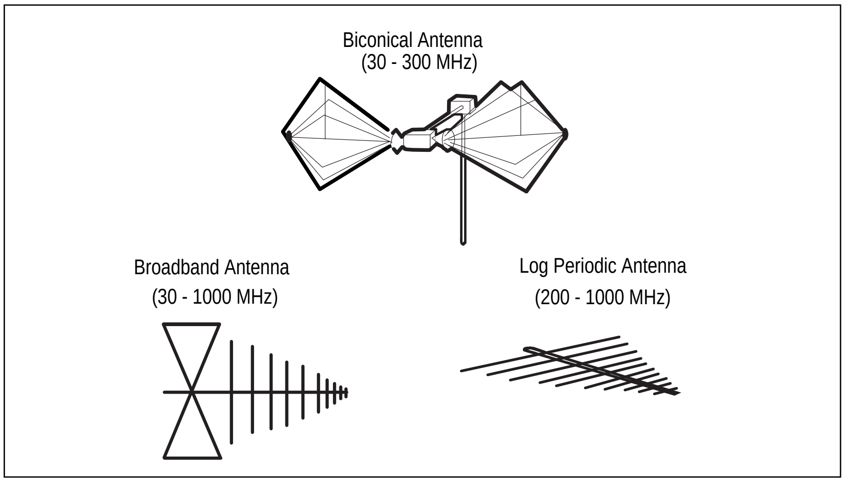


Figure B-2. Antennas used in EMI emissions measurements.

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.

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

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:

$$dB = 20 \log(V_2/V_1)$$

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

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

This is true for an impedance of 50Ω

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

$$\lambda = 3x10^8 / f\ (Hz) \quad \text{or} \quad \lambda = 300/f\ (MHz)$$

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)

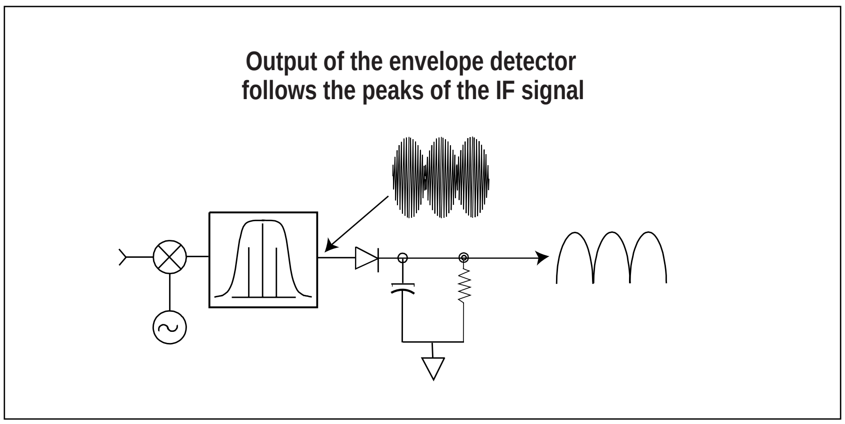


Figure D-1. Peak detector diagram.

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.

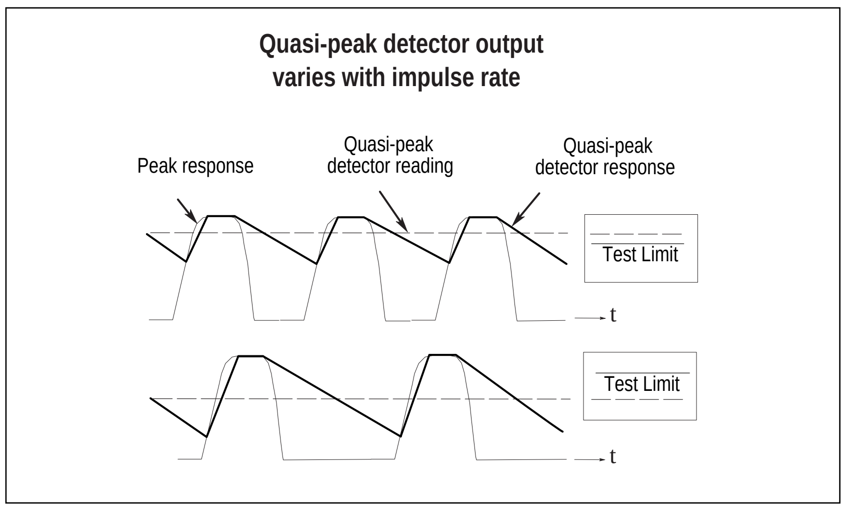


Figure D-2. Quasi-peak detector response diagram.

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.

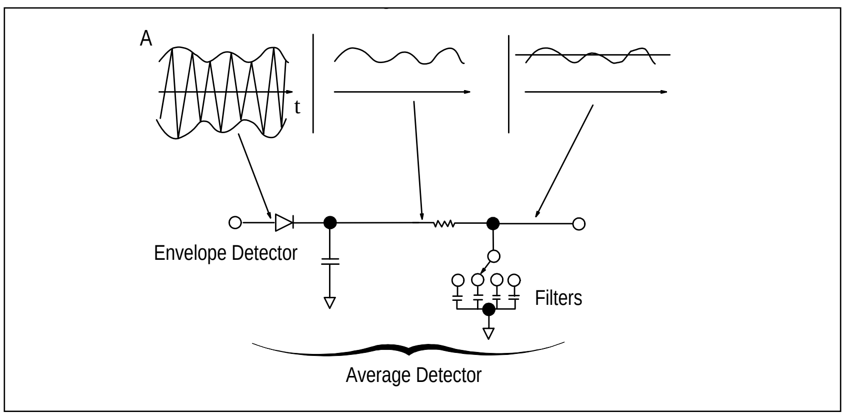


Figure D-3. Average detection response diagram.

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,
Hong Kong
Tel: (852) 2599 7777
Fax: (852) 2506 9285

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