Agilent X-Series Signal Analyzer

This manual provides documentation for the following analyzers:

PXA Signal Analyzer N9030A

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

CXA Signal Analyzer N9000A

MXE EMI Receiver N9038A

EMC Measurement Application Measurement Guide

Agilent Technologies

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1 EMC Measurements

The EMC measurement application enables you to perform precompliance conducted and radiated emissions tests to both commercial and MIL-STD requirements. It provides better sensitivity, accuracy and reduces test margins, across the X-Series signal analyzers, so you can make more precise measurement. The wide range of features enables you to:

- Set up frequency ranges, gains, bandwidths and dwell time
- Scan a frequency range and display the results in log or linear format, search for signals, measure the peak, quasi-peak and average values of the signal and place the results in a table
- Use the Signal List feature to mark and delete unwanted signals, leaving only those of interest
- Identify signals that fail the regulatory agency limit

The Role of Precompliance in the Product Development Cycle

To ensure successful electromagnetic interference (EMI) compliance testing, precompliance testing has been added to the development cycle. In precompliance testing, the electromagnetic compatibility (EMC) performance is evaluated from design through production units.

It is important to have a strategy that will help you test for potential EMI problems throughout the product development cycle. It is also important to have equipment and processes in place that will allow you to observe how close you are to compliance at any given time in the development cycle. This reduces the time and cost associated with final compliance testing.

2 Conducted Emissions Measurements

Conducted emissions testing focuses on emissions that are conducted along a power line that are generated by the device under test (DUT). The transducer that is typically used to couple the emissions of the power line to the signal analyzer is a line impedance stabilization network (LISN).

The regulatory limits specify the maximum DUT emission energy, usually in dBμV, detected by the LISN. The test range for these measurements is typically 150 kHz to 30 MHz, though some limits may start as low as 9 kHz, depending on the regulation.

Making Conducted Emission Measurements

CAUTION Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

See the AMPTD Y Scale menu for details on setting internal attenuation to prevent overloading the analyzer.

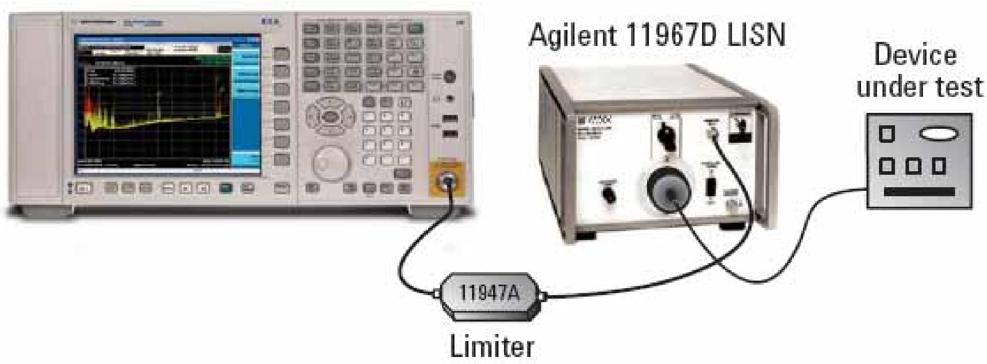
CAUTION To prevent the signal analyzer input from possible damage that could be caused by high level transient signals that could be produced by the LISN, it is recommended that an 11947A Transient Limiter be used whenever conducted emissions testing is done with the use of a LISN.

Setting up and making an ambient measurement

This section demonstrates how to set up and perform conducted emission tests in the 150 kHz to 30 MHz range.

NOTE Determine which regulatory requirements you will be testing to prior to starting the following procedure.

Step	Action	Notes
1 Test Set Up	a. Connect device under test (DUT), LISN, and Limiter to the signal analyzer as shown below:	Ensure that the power cord between the DUT and the LISN is as short as possible. The power cord can become an antenna if allowed to be longer than necessary.

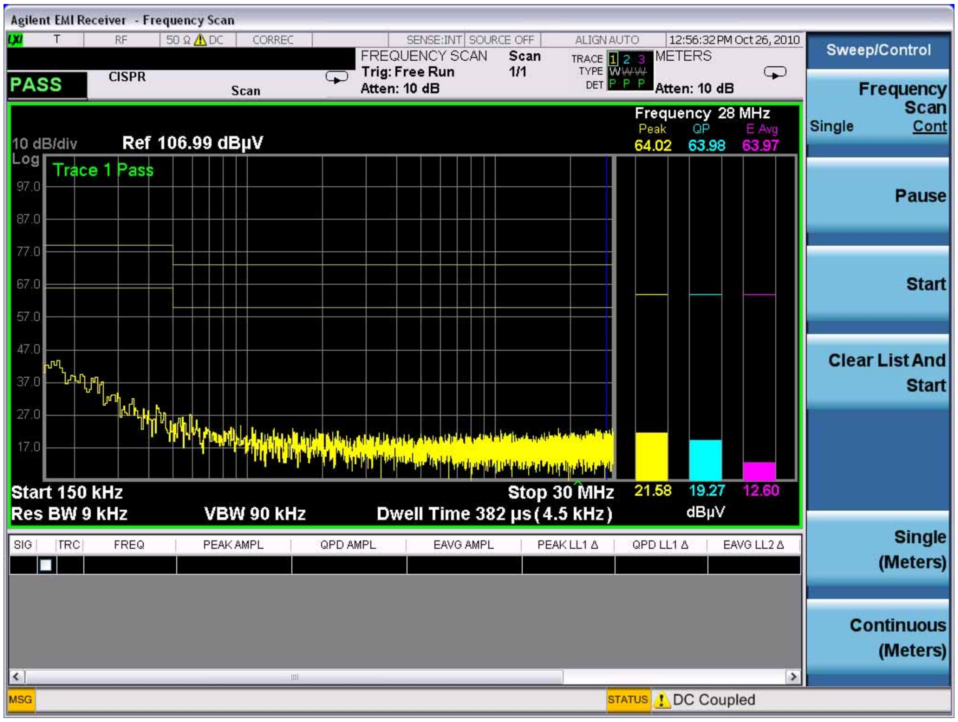


Step	Action	Notes
2 Turn on the signal analyzer.	a. Press the front-panel power key.	
3 Select the EMC mode.	a. Press **Mode, EMI Receiver**.	
4 Open the scan table and select the desired range	a. Press **Meas Setup**, **Scan Table**, **Range 2**, **Range** to **On**.	Deselect any other range that has a green check.

5 Load Quasi-peak limit line	a. Press **Recall**, **Data**, **Limit Lines 1**, **Open**. b. Select `My Documents, EMC limits and Ampcor, Open, Limits, Open, Files of type.lim`, c. Scroll to `EN 55022, Class A Cond, Quasi-peak.lim, Open`.	The limit line will be turned on after loading, If no data exists for Trace 1, the Limit Line will not display.

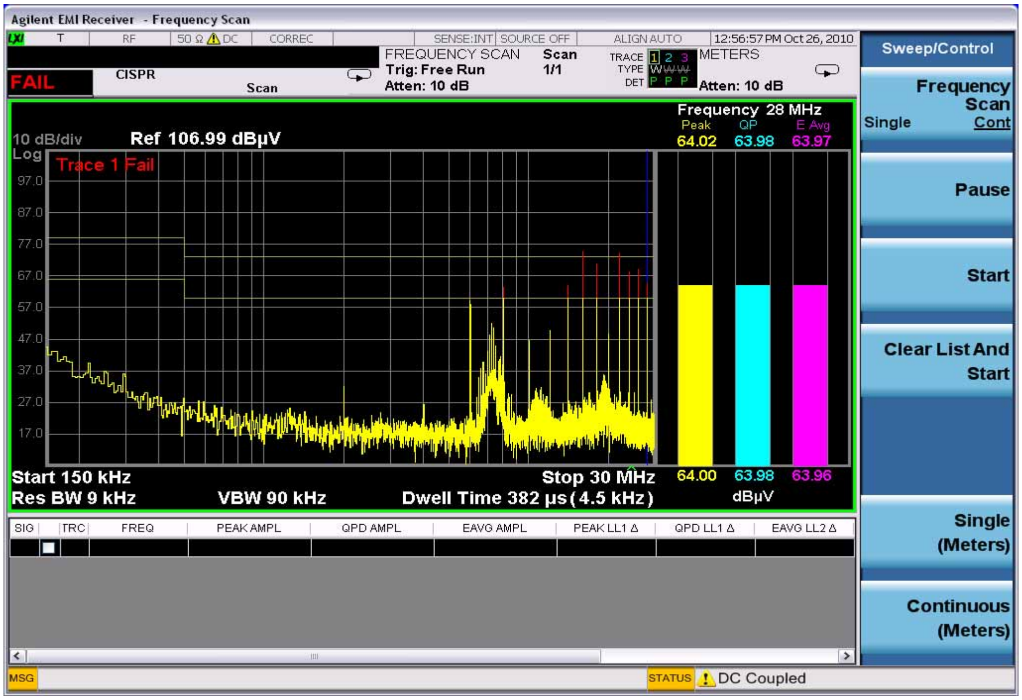
Step	Action	Notes
6 Load Average limit line	a. Press **Recall**, **Data**, **Limit Lines 2**, **Open**. b. Scroll to `EN 55022, Class A Cond, Average.lim, Open`	
7 Change EMI Average detector to compare to Limit Line 2	a. Press **Meas Setup**, **Detectors (Measure)** b. Select **Detector**, **Detector 3** c. **Limit for Δ**, **Limit 2**, **Enter**	
8 Show limit lines.	a. Press **Sweep Control**, **Start**, **Stop**.	
9 Load correction factors for the LISN	a. Press **Recall**, **Data**, **Amplitude Correction 1, Open** b. Select `My Documents, EMC limits and Ampcor, Open, Ampcor, Open, Ampcor Files of type.ant` c. Select **LISN-10A**, **Open**.	This places the corrections for the LISN in Amplitude Correction 1. These correction factors compensate for the losses of the LISN.
10 Add correction factors for the limitor in correction factor 2	a. Press **Recall**, **Data**, **Amplitude Correction 2**, **Open**. b. Select `My Documents, EMC limits and Ampcor, Open, Ampcor, Open, Files of type.oth` c. Select **11947A**, **Open**.	
11 Insure that the correction factors are on	a. Press **Input/Output**, **More 1 of 2**, **Corrections**, **Correction 1**, **On**, **Correction 2**, **On**.	
12 Insure that the input is DC coupled	a. Press **Input/Output**, **RF Input**, **RF Coupling DC**.	

Step	Action	Notes
13 Update the scan	a. Press **Sweep/Control**, **Start**.	View the ambient emissions (with the DUT off). If emissions above the limit are noted, the power cord between the LISN and the DUT may be acting as an antenna. Shorten the power cord to reduce the response to ambient signals.



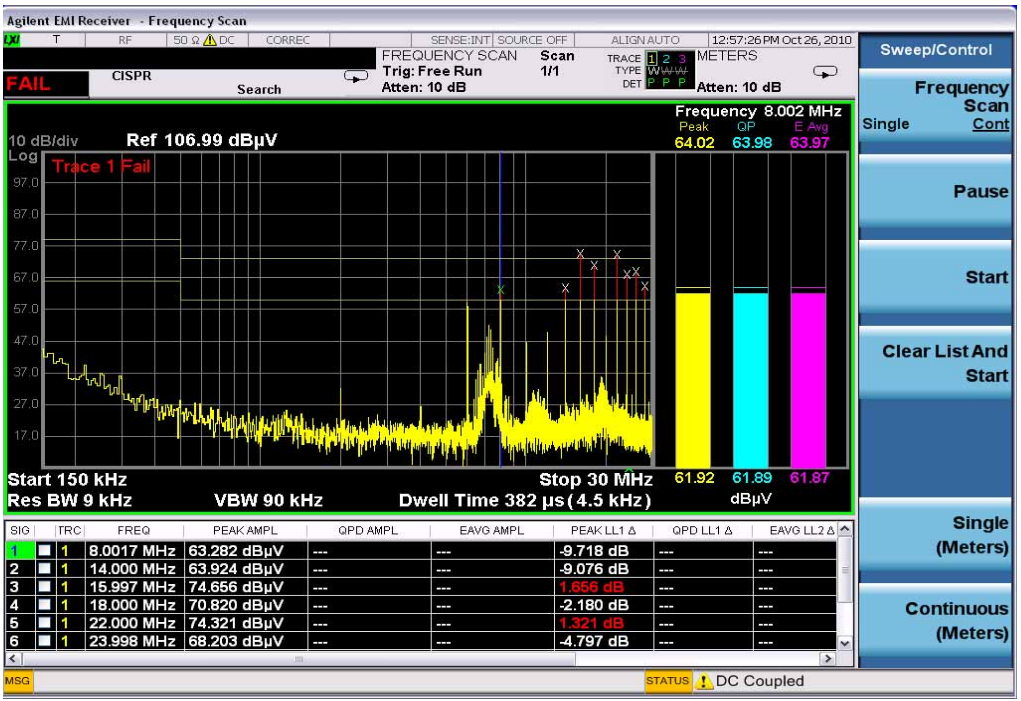
Running Frequency Scan

Step	Action	Notes
1 Turn on the DUT and scan	a. Turn the DUT on. b. Press **Meas Setup**, **Scan Sequence**, **Scan Only**, **Sweep/Control**, **Start**.	Signals above the limit are designated in red.
2 Stop the scan	a. Press **Sweep/Control**, **Stop**	This step will not be necessary if the measurement has completed the number of scans set or the desired time.



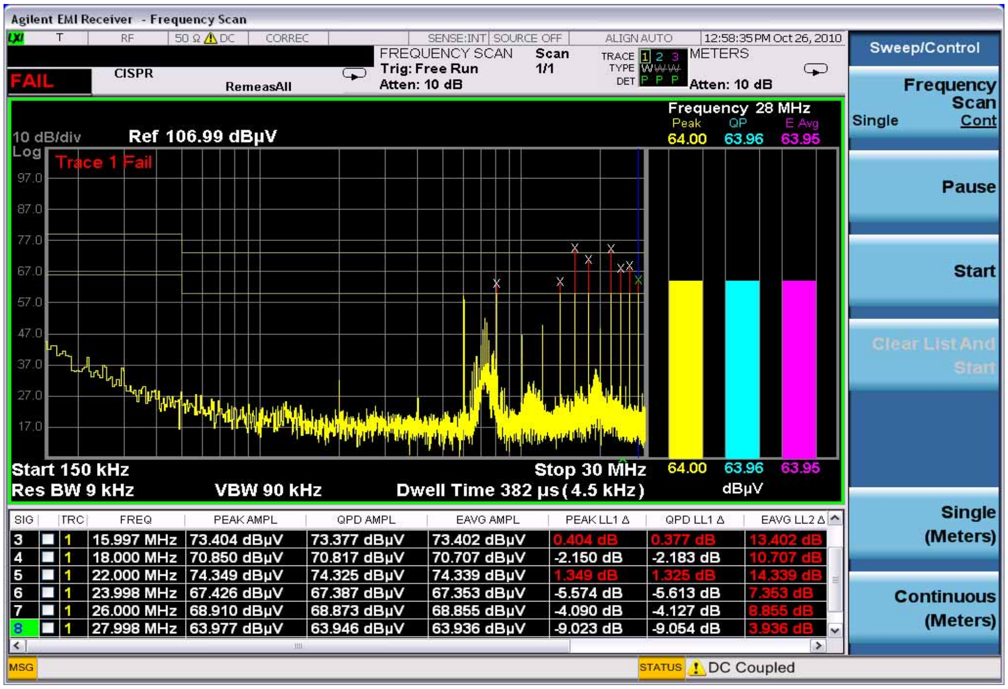
Adding signals to the signal list

Step	Action	Notes
1 Clear any existing signal list	a. Press **Meas Setup**, **Signal List**, **Delete Signals**, **Delete All**	
2 Switch to scan and search	a. Press **Meas Setup**, **Scan Sequence**, **Search Only**	
3 Set the search criteria to peak criteria and limits	a. Press **Meas Setup**, **More 1 of 2**, **Limits**, **Search Criteria**, **Peak Criteria and Limits**	
4 Add signals to the Signal List	a. Press **Sweep/Control**, **Start**	



Measuring the Quasi-peak and average values of the signals

Step	Action	Notes
1 Perform a Re-measure on all signals in the list	a. Press **Meas Setup**, **Scan Sequence**, **(Re)measure**, **(Re)measure**, **All Signals**, **Sweep/Control**, **Start**.	



Step	Action	Notes
2 Review the measurement results		The delta to Limit Line values should all be negative. If some of the measurements are positive, there is a problem with conducted emissions from the DUT.

Measurement tip

If the signals you are looking at are in the lower frequency range of the conducted band, 2 MHz or lower, you can reduce the stop frequency to get a closer look. Note that there are fewer points to view. You can add more data points using the scan table. The default setting in the scan table is two data points per BW or 4.5 kHz per point. To get more data points, change the points per bandwidth to 2.25 or 1.125 to give four or eight points per BW.

3 Radiated Emissions Measurements

Radiated emissions measurements are not as strainghforward as conducted emissions measurements. There is the added complexity of the ambient environment, which could interfere with measuring the emissions from a device under test (DUT).

Making Radiated Emission Measurements

CAUTION Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

See the AMPTD Y Scale menu for details on setting internal attenuation to prevent overloading the analyzer.

Setting up and making an ambient measurement

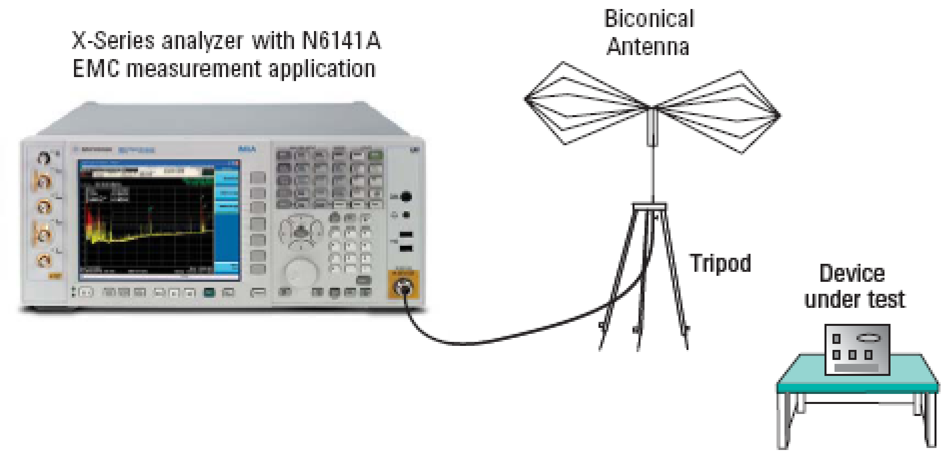
This section demonstrates how to set up and perform radiated emission tests in the 30 to 300 MHz range.

NOTE Determine which regulatory requirements you will be testing to prior to starting the following procedure.

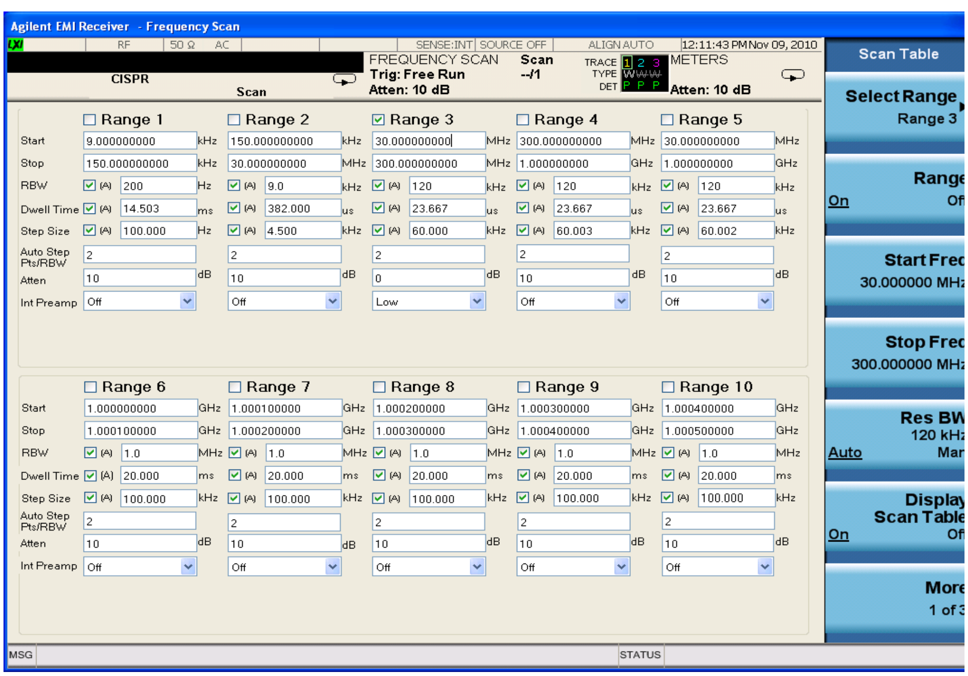
Even if you only have access to a small shielded enclosure, you can still make valuable measurement of your device. Emission signals found in the small chamber can save you time later on in an open area test site by providing information about the emissions of interest.

Step	Action	Notes
1 Test Set Up	a. Arrange the antenna, DUT and signal analyzer as shown below:	Separate the antenna and the device under test (DUT) as specified by the regulatory agency requirements. If space is limited, the antenna can be moved closer to the DUT and you can edit the limits to reflect the new position. For example, if the antenna is moved from 10 meters to 3 meters, the amplitude must be adjusted by 10.45 dB. It is important that the antenna is not placed in the near field of the radiating device.

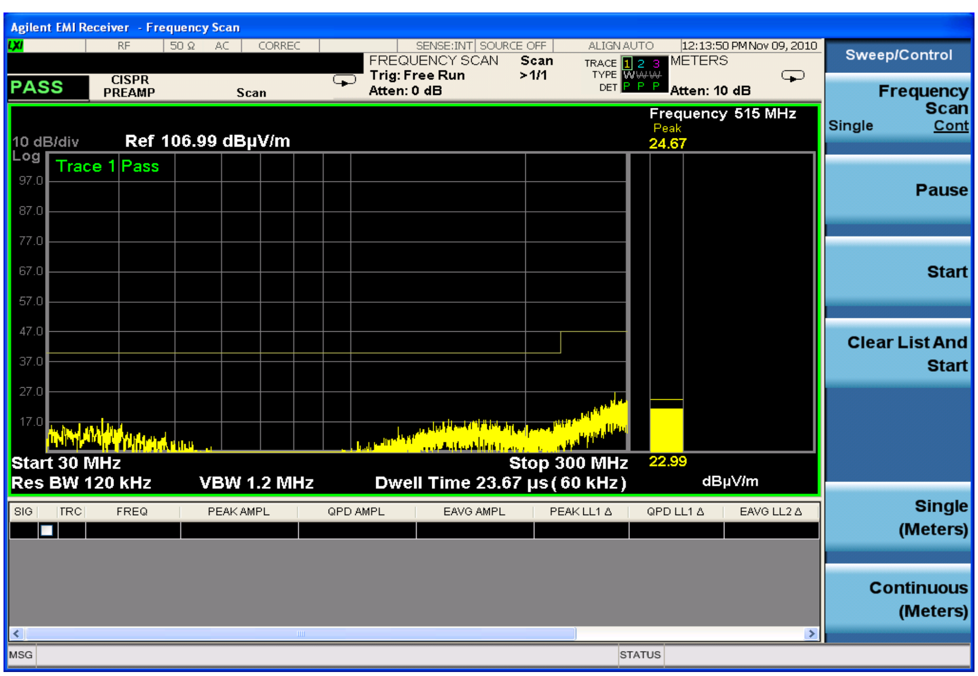
Step	Action	Notes



Step	Action	Notes
2 Turn on the signal analyzer.	a. Press the front-panel power key.	
3 Select the EMC mode.	a. Press **Mode, EMI receive**r.	
4 Open the scan table and select the desired range	a. Press **Meas Setup**, **Scan Table**, **Range 3** to **On**.	Deselect any other range that has a green check.
5 Set the attenuation and internal amplifier	a. Press **Meas Setup**, **Scan Table**, **More 1 of 3**, **Attenuation**, **0**, **dB**, **Internal Preamp**, **Low Band**.	

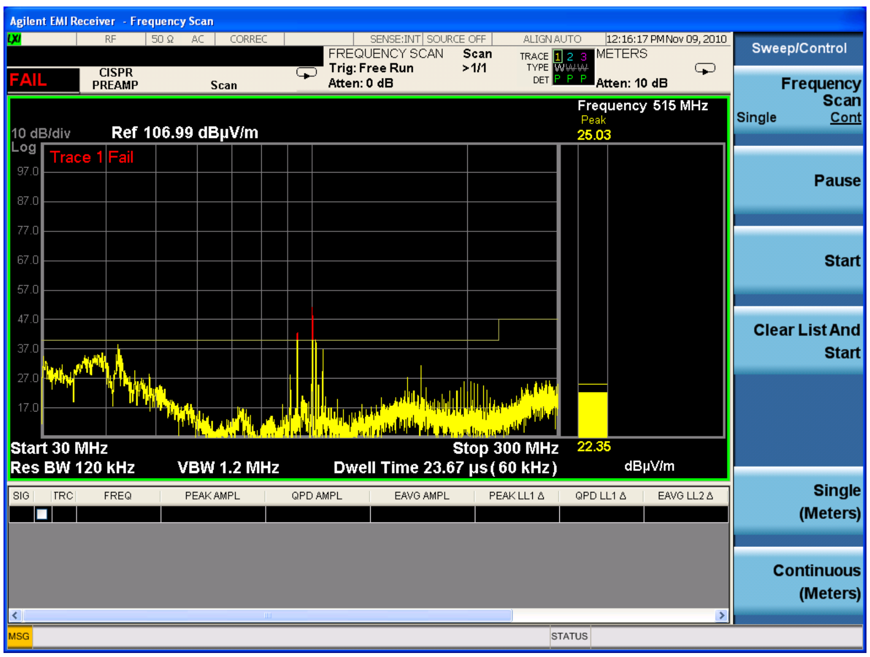


Step	Action	Notes
6 Load limit lines	a. Press **Recall**, **Data**, **Limit Lines 1**, **Open**. b. Select `My Documents, EMC limits and Ampcor, Open, Limits, Open, Files of type .lim`, **Open** c. Scroll to `EN 55022, Class A Rad (10m), Open`.	
7 Load correction factors for the biconical antenna	a. Press **Recall**, **Data**, **Amplitude Corrections 1, Open** b. Select `My Documents, EMC limits and Ampcor, Open, Ampcor, Open, Ampcor Files of type .ant` c. Select **Biconical (30 MHz to 300 MHz)**, **Open**.	
8 Turn limits and corrections on.	a. Press **Sweep Control**, **Start**, **Stop**.	



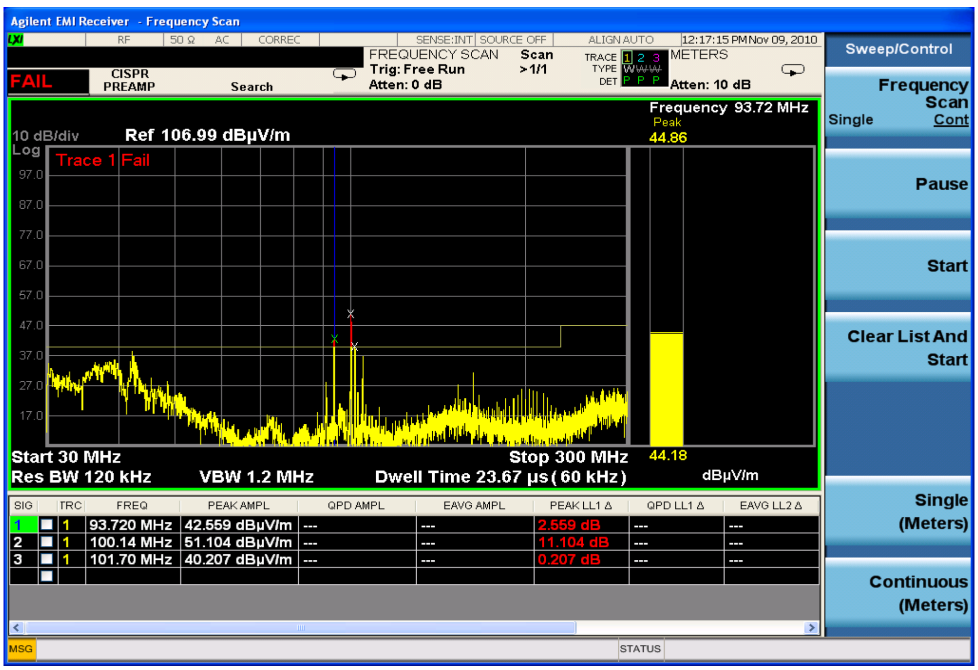
Running Frequency Scan

Step	Action	Notes
1 Clear any existing signal list	a. Press **Meas Setup**, **Signal List**, **Delete Signals**, **Delete All**	
2 Turn on the DUT and start frequency scan	a. Turn the DUT on. b. Press **Meas Setup**, **Scan Sequence**, **Scan Only** c. Press **Sweep/Control**, **Start**.	
3 Stop the scan	a. Press **Sweep/Control**, **Stop**	



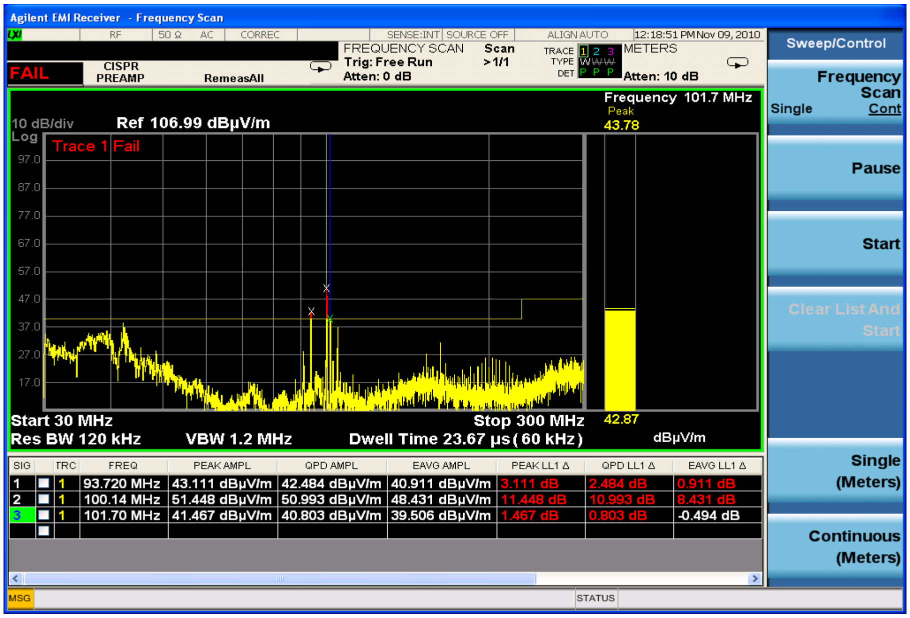
Adding signals to the list

Step	Action	Notes
1 Set the search criteria to peak criteria and limits	a. Press **Meas Setup**, **More 1 of 2**, **Limits**, **Search Criteria**, **Peak Criteria and Limits**	
2 Switch to search	a. Press **Meas Setup**, **Scan Sequence**, **Search Only**	
3 Add signals to the Signal List	a. Press **Sweep/Control**, **Start**	This places the ambient signals in the Signal List.



Measuring the Quasi-peak and average values of the signals

Step	Action	Notes
1 Measure remaining signals	a. Press **Meas Setup**, **Scan Sequence**, **(Re)measure**, **(Re)measure All Signals**. b. Press **Sweep/Control**, **Start**	



2 Review the measurement results

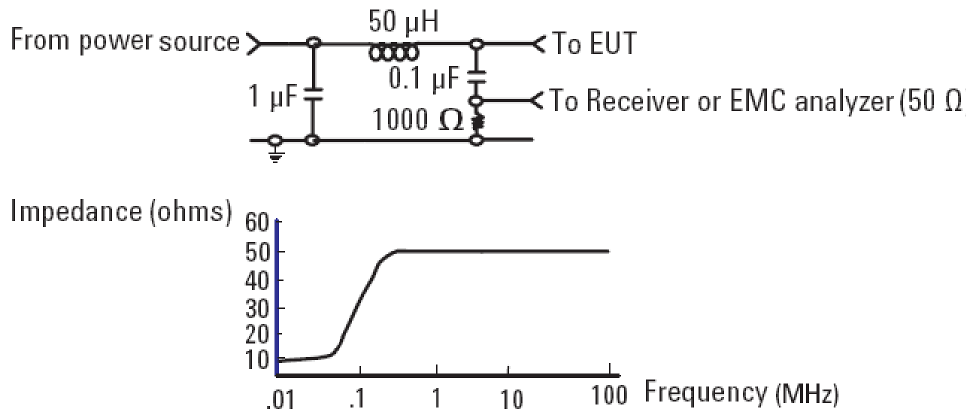
A: Line Impedance Stabilization Networks (LISN)

A line impedance stabilization network serves three purposes:

1. The LISN isolates the power mains from the device under test. the power supplied to the DUT must be as clean a possible. Any noise on the line will be coupled to the X-Series signal analyzer and interpreted as noise generated by the DUT
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 DUT are coupled to the X-Series analyzer using a high-pass filter, which is part of the LISN. Signals that are in the pass band of the high-pass filter see a 50-Ω load, which is the input to the X-Series signal analyzer

LISN Operation

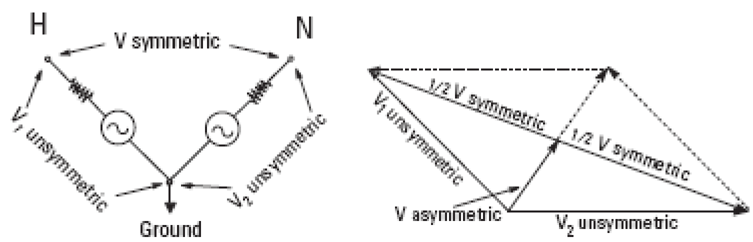
The following graphic shows a typical LISN circuit diagram for one side of the line relative to earth ground. The chart represents the impedance of the DUT port versus frequency.



The 1 µF in combination with the 50 µH inductor is the filter that isolates the mains from the EUT. The 50 µH inductor isolates the noise generated by the EUT from the mains. The 0.1 µF couples the noise generated by the EUT to the X-Series signal analyzer or receiver. At frequencies above 150 kHz, the EUT signals are presented with a 50Ω impedance.

Types of LISNs

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



V-LISN **Vector Diagram**

V-LISN: Unsymmetric emissions (line-to-ground)
∆-LISN: Symmetric emissions (line-to-line)
T-LISN: Asymmetric emissions (mid point line-to-line)

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 DUT power on or off can cause large spikes generated in the LISN.

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

B: Antenna Factors

Field Strength Units

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

P_t = total power radiated from an isotropic radiator

P_D = the power density at a distance r from the isotropic radiator (far field)

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

$R = 120\text{m}\Omega$

$P_D = E^2/R$

$E2/R = P_t / 4\pi r^2$

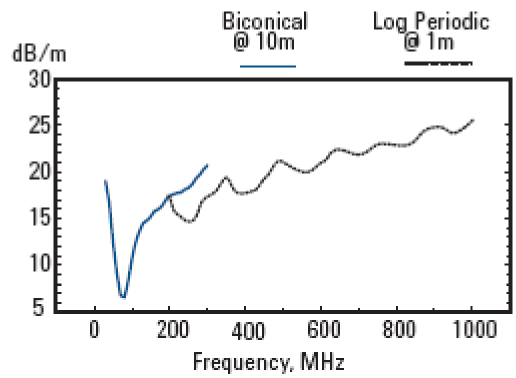
$E = (P_t \times 30)^{1/2} / r$ (V/m)

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

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)

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

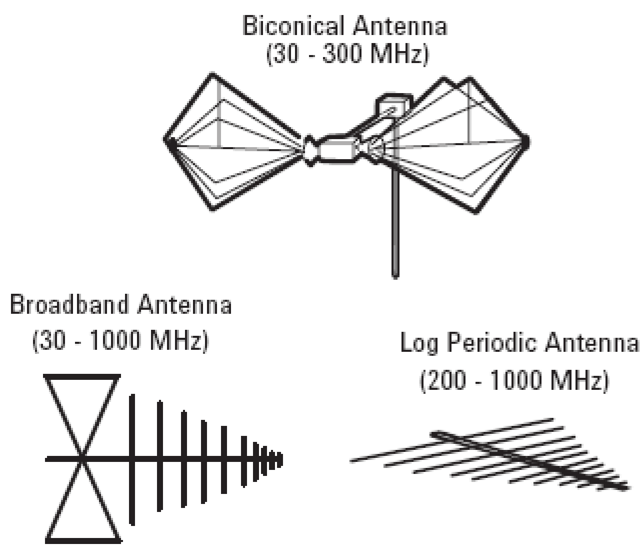
Log units: AF(dB/m) = E(dBµV/m) - V(dBµV)
E(dBµV/m) = V(dBµV) + AF(dB/m)

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

Types of antennas used for commercial radiated measurements

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

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



C: Basic Electrical Relationships

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

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

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

If the impedances are equal, the equation becomes:

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

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

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

This is true for an impedance of 50Ω.

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

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

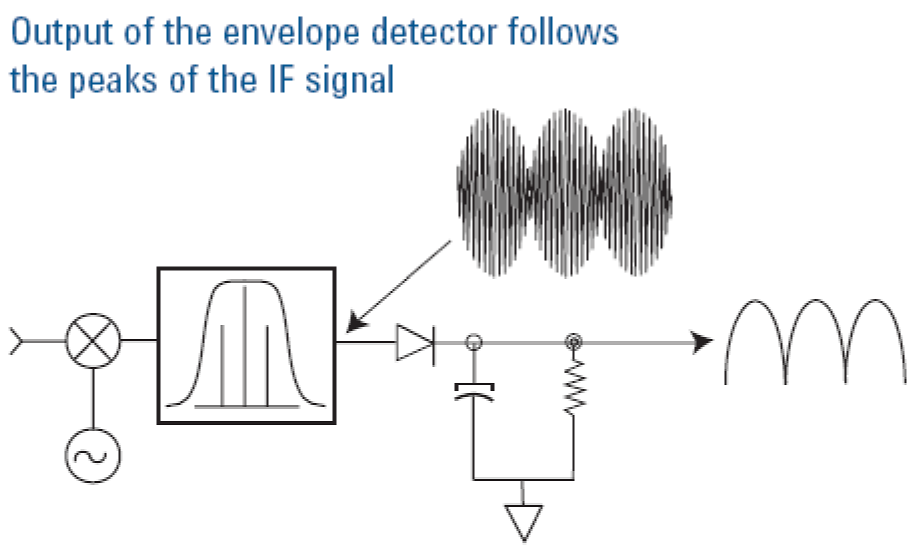
D: Detectors Used in EMI Measurements

Peak Detector

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

Peak detector operation

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



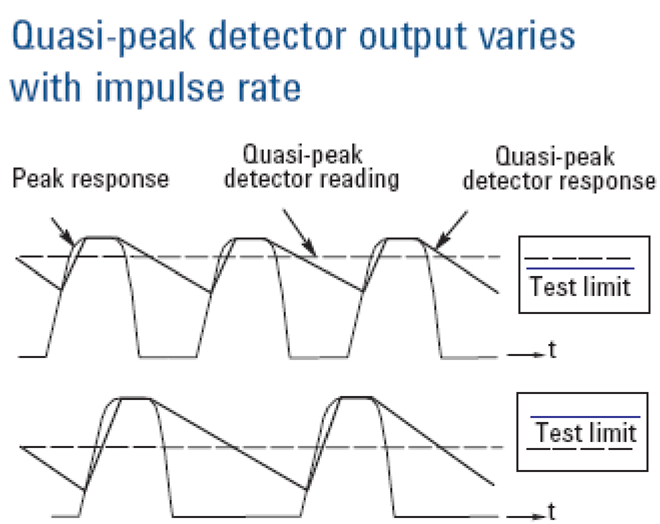
Quasi-peak Detector

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

Quasi-peak detectors always give a reading less than or equal to peak detectors, but quasi-peak measurements are much slower by two or three orders of magnitude compared to a peak detector.

Quasi-peak detector operation

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

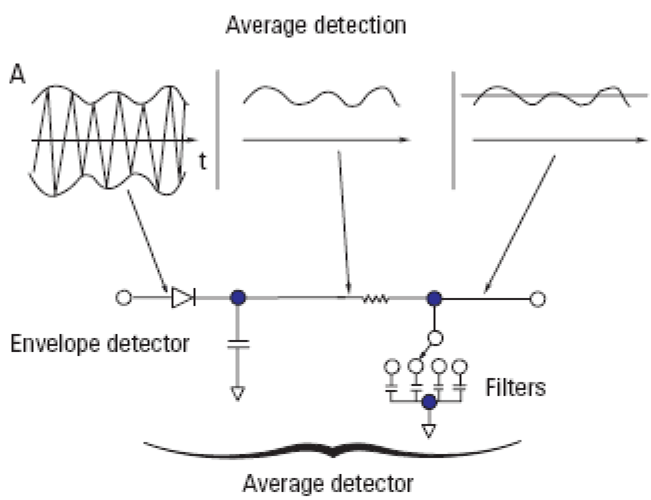


Average Detector

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.

Average detector operation

Average detection is similar in many respects to peak detection. The following graphic 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.



Glossary of Acronyms and Definitions

Ambient level

1. The values of radiated and conducted signal and noise existing at a specified test location and time when the test sample is not activated

2. Those levels of radiated and conducted signal and noise existing at a specified test location and time when the test sample is inoperative. Atmospherics, interference from other sources, and circuit noise, or other interference generated within the measuring set compose the ambient level.

Amplitude modulation

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

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

Anechoic chamber

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 semianechoic 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. 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.

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 themeasuring instrument, yields the electric field strength in volts per meter and a magnetic field strength in amperes per meter.

Antenna induced voltage

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

Antenna terminal conducted interference

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

Auxiliary equipment

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

Balun

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

Broadband emissions

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

Broadband interference (measurements)

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

Conducted interference

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

Cross-coupling

The coupling of a signal from on 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 separate networks.

Dipole

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

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

Electromagnetic compatibility (EMC)

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

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

Electromagnetic interference

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

Electromagnetic wave

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

Emission

Electromagnetic energy propagated from a source by radiation or conduction.

Far Field

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

Ground plane

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

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

Immunity

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

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

Intermodulation

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

Isotropic

Isotropic means having properties of equal values in all directions.

Mono pol

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

Narrowband emissions

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.