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2002 DeCQuTest EMC Theory Manual: 10 Emissions Tests

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10 Emissions Tests

Adrian A. Adăscăliței

Description of the different test methods, including radiated emission chamber tests, LISNs (LISN Line Impedance Stabilization Network) GTEM cells, open area test sites (OATS).

The advantages & disadvantages of each method, together with operating frequency ranges, setup information, etc.

10.1 Overview

The term conducted emissions refers to the mechanism that enables electromagnetic energy to be created in an electronic device and coupled to its AC power cord. Similarly to radiated emissions, the allowable conducted emissions from electronic devices are controlled by regulatory agencies. If a product passes all radiated emissions regulations but fails a conducted emissions test, the product cannot be legally sold.

The primary reason that conducted emissions are regulated is that electromagnetic energy that is coupled to a product's power cord can find its way to the entire power distribution network that the product is connected to and use the larger network to radiate more efficiently than the product could by itself. Other electronic devices can then receive the electromagnetic interference through a radiated path (or, much less frequently, a direct electrical connection). The frequency range where conducted emissions are regulated is typically lower than the frequency range where radiated emissions are regulated. The longer wavelengths where conducted emissions are a problem need a much larger antenna to

radiate and receive electromagnetic interference than the shorter wavelengths studied for radiated emissions.

10.2 EMC Analysis—Decision flow-chart

The manufacturer, his authorized representative or the person who places a product on the EEA market or takes it into service has to find out whether or not this product is covered by the EMC Directive and to apply its provisions, if required. The manufacturer (in the broadest sense of the Directive) must therefore make an EMC analysis on the basis of the EMC Directive.

He is the first and ultimate person responsible for the conformity of his apparatus to the Directive. Furthermore, this person is responsible for evaluating the potential EMC problems that the apparatus may or will present when used as intended, since he has assumed responsibility for its design and construction. EMC problems can be caused both by the apparatus itself, and also by its environment, the way it is installed, etc.

The European Community Directive on EMC (Describes the EC Directive on EMC including the scope, essential protection requirements, compliance, certification and marking requirements, obligations of the administration, legislation, flowchart of actions required by manufacturers and suppliers and a table of relevant standards).

In order to evaluate the applicability of commercial standards for industrial purposes, it is necessary to define the electromagnetic emissions (EME) in which the equipment will operate. In traditional military procurement, the contracting agency would assess the anticipated use of the equipment and levy appropriate requirements from European Community Directive on EMC or as an alternative, with the requirements and limits tailored as necessary to match the anticipated environment. The equipment would then be designed to meet these requirements and would be tested accordingly. However, if existing commercial equipment is to be utilized, the contracting agency generally does not have the design option and must instead determine what data are available which

describes the electromagnetic characteristics of that equipment and how well those characteristics meet its anticipated needs. Thus, it is most expedient to use European Community Directive on EMC as the basic reference for establishing EMI requirements. This is shown in the upper half of the flow chart. The procedure deviates in the centre of the chart depending on whether the equipment is a military type or a commercial type.

10.3 Radiated Emission Chamber Tests

10.3.1 The Line Impedance Stabilization Network (LISN)

As an engineer in the EMC field, it is important to understand the measurement procedures that are used to measure conducted emissions. Conducted emissions are regulated by the FCC over the frequency range 450 kHz to 30 MHz, and the CISPR 22 conducted emissions limits extend from 150 kHz to 30 MHz. When testing a device for compliance with the FCC and CISPR 22 regulatory limits, a line impedance stabilization network (LISN) must be inserted between the ac power cord of the device under test and the commercial power outlet. Due to the difference in regulated frequency ranges between the FCC and CISPR 22 regulations, the LISNs for the two have similar layouts but the component values are different. Below is a diagram of the test setup used to test compliance with conducted emissions limits.

As shown in the diagram, the ac power cord of the product under test is plugged into the input of the LISN, and the output of the LISN is plugged into the commercial power system outlet. AC power is filtered through the LISN and the product is provided with ‘unpolluted’ ac power. A spectrum analyser is connected to the LISN and measures the conducted emissions from the product under test.

The purpose of conducted emissions testing is to measure noise currents that exit the product under test’s ac power cord and make sure these currents are within the regulated limits. FCC and CISPR 22 regu-

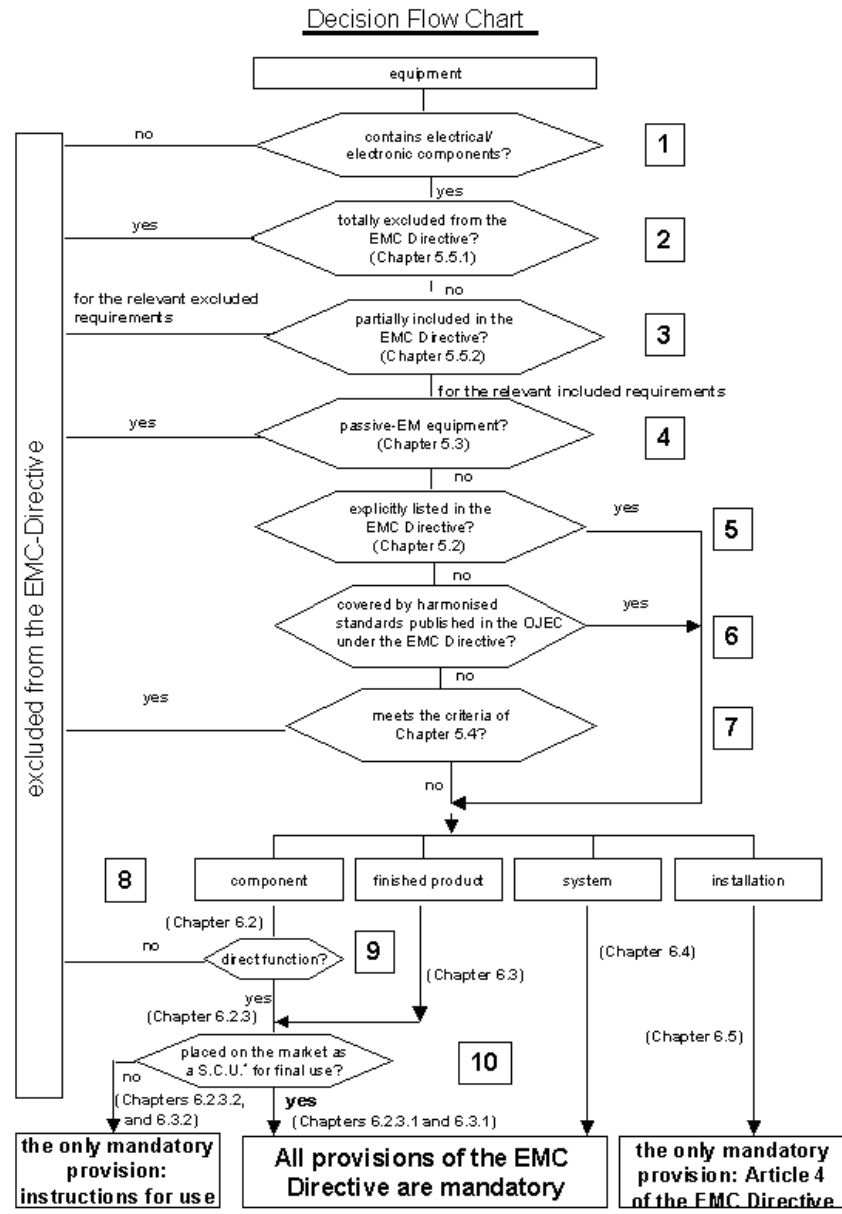


Figure 10.1: Flow Chart for the Procurement of Electromagnetically Compatible Systems or Equipment

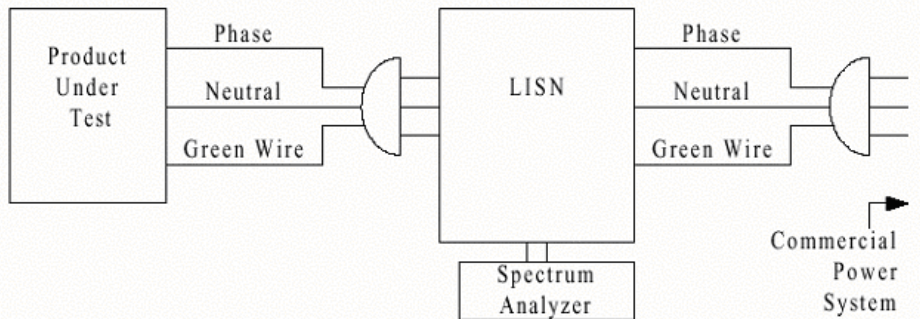


Figure 10.2: Diagram of the test setup used to test compliance with conducted emissions limits

lations require that measured data be correlatable between measurement facilities.

Since the currents exiting the device under test are dependant on the load on the ac power cord, and this load is the impedance seen by the device looking into the ac power outlet, which varies considerably over the measurement frequency range from outlet to outlet and from building to building, it is not sufficient to measure the noise currents on the power cord with a current probe.

Instead, the product under test is connected to a LISN, which stabilizes the impedance seen by the product looking out the ac power cord. This is the first of the two objectives of the LISN. The second objective of the LISN is to block external noise that exists on the power system net from entering the product's ac power cord. Any noise currents from the power system net that were to enter the product's ac power cord would add to the conducted emissions from the device. Since we are only interested in the conducted emissions that emanate from the device under test, it is important that the LISN prevent noise from the power system net from entering the product's ac power cord. The LISN must satisfy both of these objectives over the entire conducted emissions frequency range (450 kHz–30 MHz for FCC regulations and 150 kHz–30 MHz for CISPR 22 regulations), yet still allow the 60 Hz power to reach the device under

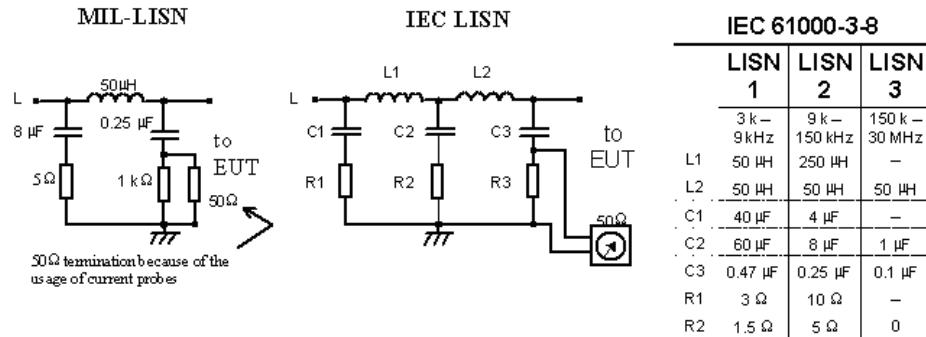


Figure 10.3: LISN Designs for MIL-STD 461E and IEC 61000-3-8

test.

10.3.1.1 LISNs

LISN—Line Impedance Stabilization Network

There are two major differences in the instrumentation of these two standards (IEC 61000-3-8 and CE101):

1. IEC 61000-3-8 measures the voltage at the input of an LISN whereas CE101 measure the current with a current probe.
2. The LISN designs are different (see Fig. 10.3); their corresponding impedance characteristics are depicted in Fig. 10.4 in the 'worst-case' scenario where the line impedance is $0.2 + j50\mu$.

Limits The voltages measured in IEC 61000-3-8 can be converted to currents with knowledge of the line-ground impedance of the LISNs.

The relationship between the measured quantities of CE101 and IEC 61000-3-8 depends on the impedance of the LISNs used. The current measurements of CE101 can be correlated to the voltage measurements of IEC 61000-3-8 using the impedance values plotted in Fig. 10.4. For the range 30 Hz to approximately 3 kHz, the correlation is approximately

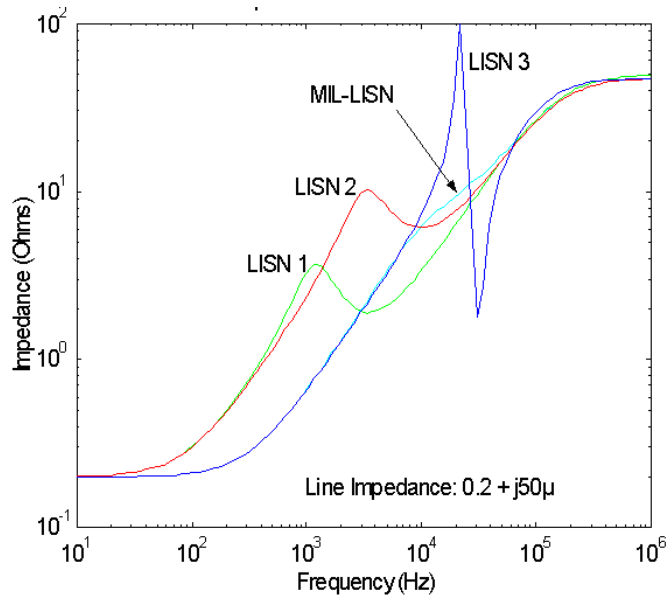


Figure 10.4: Impedance Characteristics of MIL-STD-461E and IEC 61000-3-8 LISNs In contrast to CE101 and IEC 61000-3-2, IEC 61000-3-8 indicates no special concern for distortion of the source of power. IEC 61000-3-8 measures voltage at the terminals of the LISNs.

linear, but from 3 kHz to 10 kHz resonance phenomena dominates the impedance characteristics.

Conclusions IEC 61000-3-8 certified mains-signaling equipment can be considered to meet CE101 requirements. Because of its rather restricted scope, IEC 61000-3-8 is not expected to be of much significance for industrial applications.

1. Interconnecting cables that hang closer than 40 cm to the ground shall be folded back and forth forming a bundle 30 to 40 cm long, hanging approximately in the middle between ground plane and table.

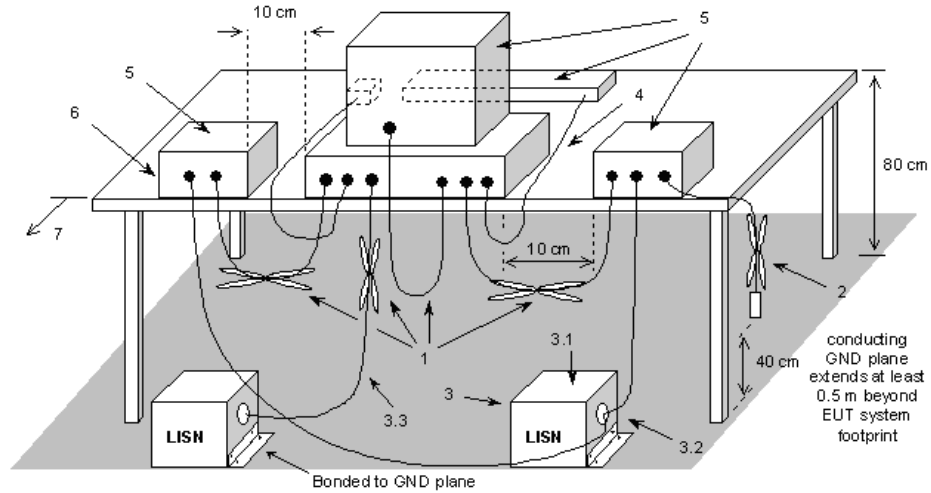


Figure 10.5: Tabletop Set-up, General Rules

2. I/O cables that are connected to a peripheral shall be bundled in center. The end of the cable may be terminated if required using correct terminating impedance. The total length shall not exceed 1 m.
3. EUT connected to one LISN. Unused LISN connectors shall be terminated in 50 W. LISN can be placed on top of, or immediately beneath the ground plane (conducted tests only).
 - a) All other equipment powered from second LISN.
 - b) Multiple outlet strip can be used for multiple power cords of non-EUT equipment.
 - c) LISN at least 80 cm from nearest part of EUT chassis.
4. Cables of hand-operated devices, such as keyboards, mice, etc., have to be placed as close as possible to the host.
5. Non-EUT components of EUT system being tested.

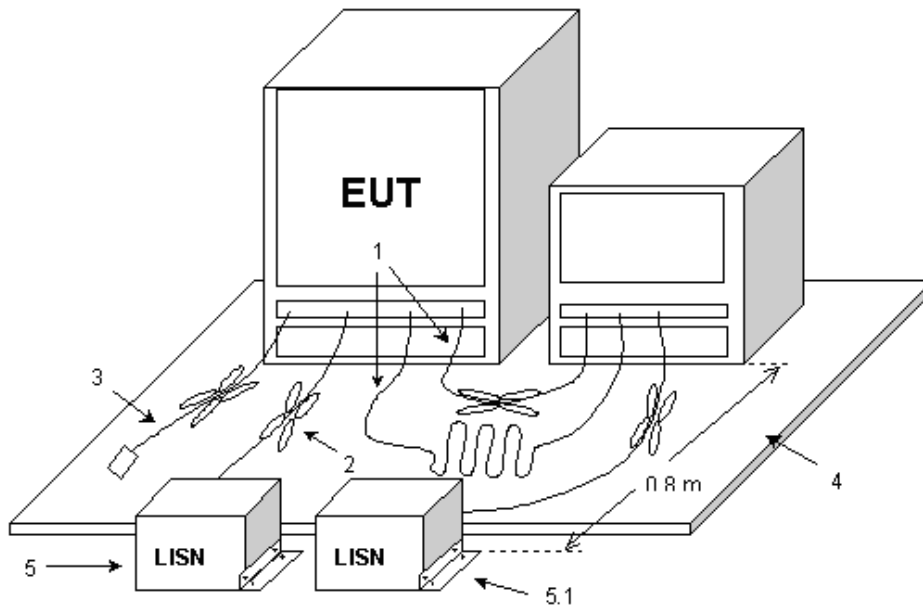


Figure 10.6: Floor Standing Steps

6. Rear of EUT including peripherals shall be aligned and flush with rear of table top.
7. Rear of table
1. Excess I/O cables shall be bundled in centre. If bundling is not possible, the cables shall be wound in turns. Bundling shall not exceed 40 cm in length.
2. Excess power cords shall be bundled in the centre or shortened to appropriate length.
3. I/O cables which are not connected to a peripheral shall be bundled in the centre. The end of the cable may be terminated if required using correct terminating impedance. If bundling is not possible, the cable shall be wound in turns.

4. EUT and all cables shall be insulated from ground plane by 3 to 12 mm.
5. EUT connected to one LISN. LISN can be placed on top of, or immediately beneath ground plane

10.3.1.2 GTEM cells are used for Radiated Tests

Instrumentation There are some differences in the instrumentation requirements of RS105 and IEC 61000-4-20. The bandwidth requirement on the monitoring equipment is 200 MHz for RS105 and 120 kHz for IEC 61000-4-20. For the military test, EUT power is supplied through LISNs and terminal protection devices (TPDs) whereas for the civilian test a line filter is used. The last difference is relatively minor: B-dot and D-dot sensors are used with integrators in RS105 to determine the field levels whereas direct field sensors are used in IEC 61000-4-20. The use of these sensors needs further clarification as they are not widely employed in the EMI/EMC community. In particular, the bandwidth of the sensors (the frequency below which they respond to the time derivative of the fields) should be higher than the cut-off frequency of the TEM cell (the frequency above which higher order modes can propagate). For a 10 ns time-to-peak, the bandwidth should be at least 100 MHz, but considering that 10 ns is the longest time-to-peak acceptable for RS105, the bandwidth should be around 1 GHz. This figure should also represent the integrator bandwidth. For such high bandwidths the integrators will most likely be active.

Measurement Techniques

Calibration There is essentially no difference in the calibration techniques of the military and civilian tests. In both calibration is done without the EUT in place. A field reading is obtained at the various positions within the volume occupied by the EUT and a probe is used to monitor the pulse characteristics.

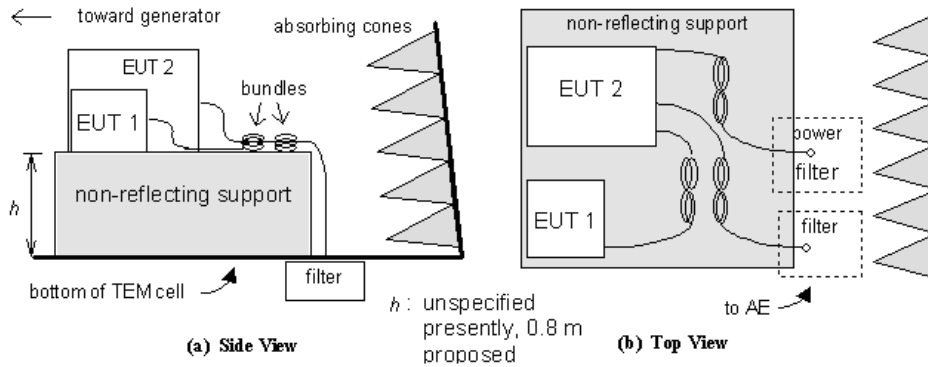


Figure 10.7: Setup of IEC 61000-4-20, draft 5.95

Test Setup In RS105 all cables are shielded and led directly outside the TEM cell so as to exclude them from the test; only the EUT chassis is considered. Although cables are not treated in detail in IEC 61000-4-25 we make reference to their treatment in IEC 61000-4-20 as probably applicable to IEC 61000-4-25. In IEC 61000-4-20, cables are included in the test and are arranged as in Fig. 10.7. There are numerous issues to be considered in the test procedures, of which the more important issues are discussed in the ensuing material.

10.3.2 Open Area Test Sites (OATS)

10.3.2.1 Introduction

The measurements of radiated emissions (RE) from equipment, apparatus, or instruments and the radiation susceptibility (RS) of such an equipment/apparatus/instrument constitute two basic electromagnetic interference and electromagnetic compatibility (EMI/EMC) measurements. The purpose of radiation susceptibility testing is to determine the degradation in equipment performance caused by externally coupled electromagnetic energy. The permissible limits to such degradation are normally specified by the user. The specification is in the form of measurable video, audio, or other form of indication when the intensity of externally

coupled electromagnetic interference exceeds a specified threshold.

Equipment such as radio or radar transmitters is designed to deliver electromagnetic energy at a specified frequency. However, such transmitters are also found to radiate energy at several harmonic and subharmonic frequencies and also at a variety of spurious frequencies. Although such radiations tend to be at significantly lower power levels when compared to the main frequency of operation, they still constitute a source of electromagnetic interference. Further, electronic apparatus not designed as a radiator also tends to have unintentional leakage sources. Such electromagnetic energy leakage sources may be considered electrically small, and the leakage fields, which give rise to surface currents, can be modelled as equivalent electric and magnetic short-dipole sources. Each electrically small source can be characterized, to be perfectly general, as three orthogonal electric and magnetic dipole moments having an amplitude and phase. All such dipole sources may then be combined as vectors to form a composite equivalent source. An elaborate set of measurements will be required to characterize the source of radiation. If one knows a priori that the source may be characterized by one kind of dipole moment only (either electric or magnetic), the relative phase measurement is not needed. Often in practical radiated emission measurements, the interest is in measuring the electrical field strength due to radiated emissions (from the equipment under test) at a specified distance. Several approaches are available for conducting these measurements.

The basic model for an OATS with two antennas over a ground plane is shown in Fig. 10.8. The transmitting antenna height is h_1 and the receiving antenna height is h_2 respectively.

Open site measurement is the most direct and universally accepted standard approach for measuring radiated emissions from an equipment or the radiation susceptibility of a component or equipment.

The basic principle of measurement for testing radiated emissions is illustrated in Fig. 10.9. In this setup, with the EUT switched on, the receiver is scanned over the specified frequency range to measure electromagnetic emissions from the EUT and determine the compliance of these data with the stipulated specifications.

Fig. 10.10 illustrates the principle for the measurement of radiation

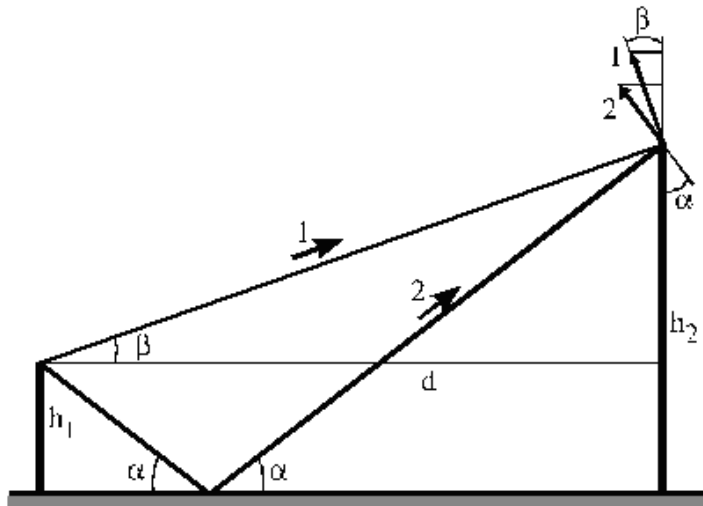


Figure 10.8: OATS model with direct (1) and indirect (2) path

susceptibility. In this setup, the EUT is placed in an electromagnetic field created with the help of a suitable radiating antenna.

The intensity of the electromagnetic field is varied by varying the power delivered to the antenna by the transmitter amplifier (signal generator). Specific performance factors of the EUT (or the component under test) are then observed under different levels of electromagnetic field intensity to check for performance compliance at the designated levels.

10.3.2.2 Test Site

With the help of a proper test site and a calibrated receiving antenna, radiated emissions from equipment under test over a specified frequency band can be measured observing various precautions. Similarly, using a calibrated transmitting antenna, susceptibility of equipment under test can be checked under specified field conditions.

If these measurements are done in a room, or an enclosed area, it

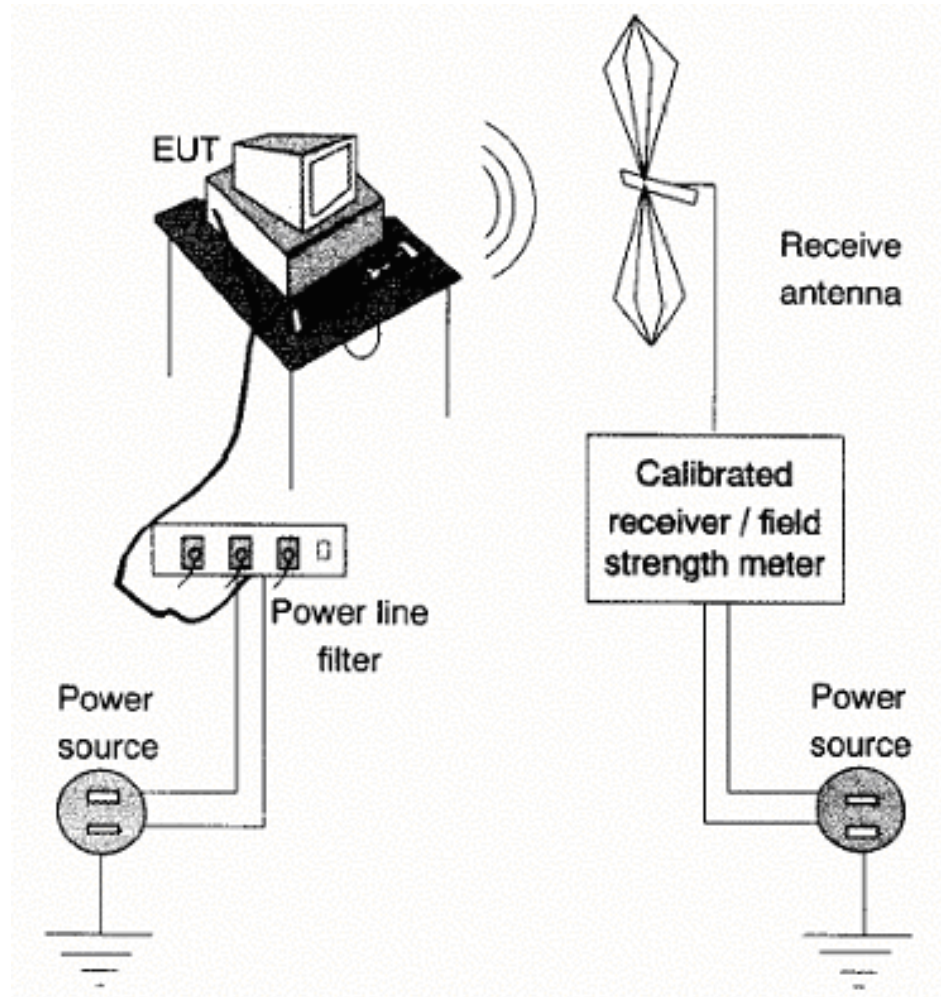


Figure 10.9: Principle of measurement of radiated emissions

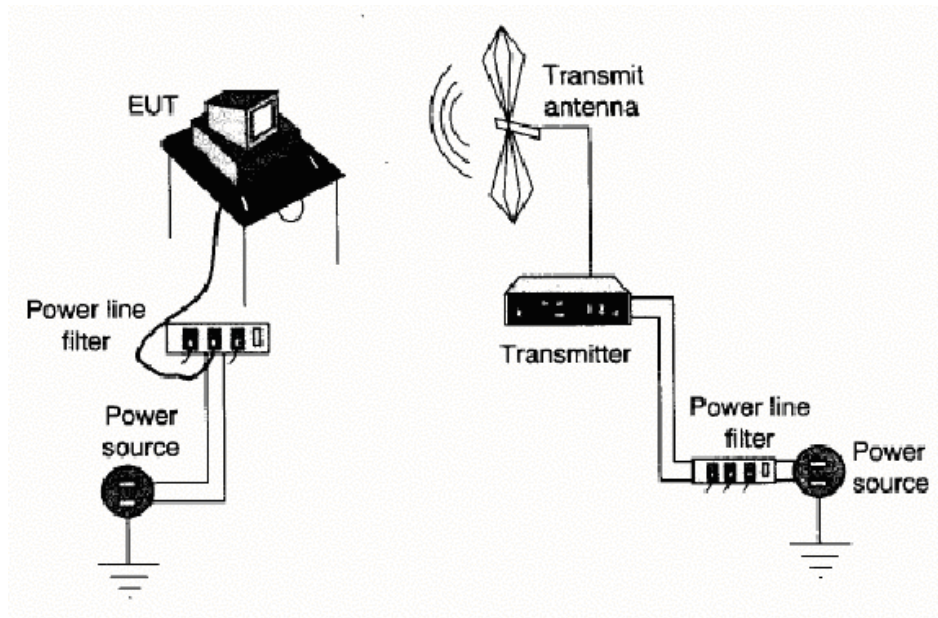


Figure 10.10: Schematic for measurement of radiation susceptibility

is possible that reflections or scattered signals from walls, floor, and ceiling will be present. The presence of such scattered signals will corrupt the measurements. However, if these measurements are done in a proper open-area test site, the scattered signals and reflections will not be present.

10.3.2.3 Test Antennas

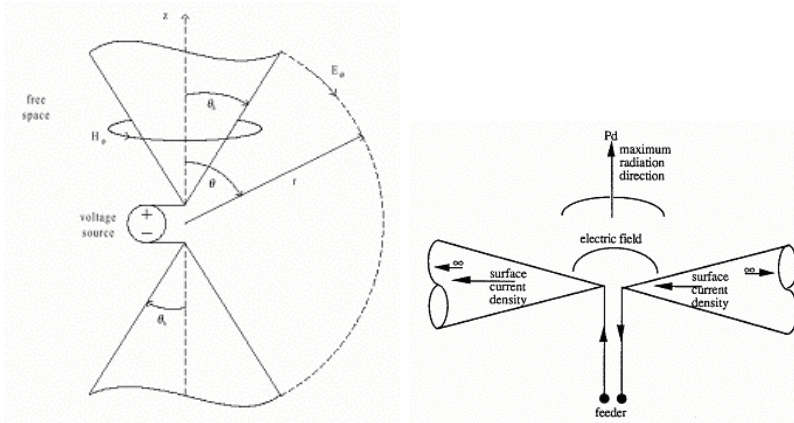
A convenient approach to illuminate an equipment under test with known field strengths is to use exact half-wavelength long dipoles at fixed frequencies. These can be made and constructed with relative ease. Further, if the cross-section of these dipoles is properly engineered (say about 15 cm diameter), battery-operated radio frequency (RF) sources can be housed in them. Such an arrangement produces good field patterns with known antenna gain and can serve as a fairly accurate field strength stan-

Table 10.1: Commonly Used Test Antennas

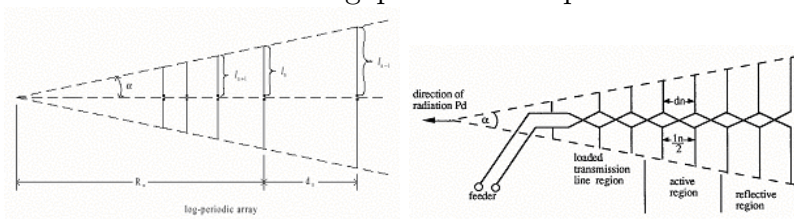
Antenna type	Frequency, MHz
Rod antenna	0.01–30
Loop antenna	0.01–30
Biconical antenna	30–220
Dipole antenna	30–1000
Log periodic antenna	200–1000
Conical log spiral	200–10,000
Double ridged waveguide	1000–18,000
Waveguide horn	above 1000

dard. This arrangement is superior when compared to connecting a test antenna to a signal source using coaxial cable that might distort the field pattern. Configuration of the test antenna depends on the frequency of operation. Table 10.1 gives a list of some commonly used test antennas and the approximate useful frequency range for each. Fig. 10.11 shows a photograph of several types of these test antennas.

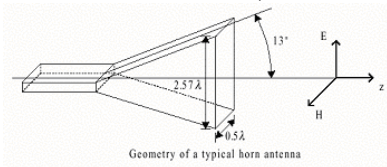
Open-area test site (OATS) measurement is an internationally accepted standard for measuring radiated emissions. It has no inherent frequency limitations, unlike the laboratory techniques described in Chapter 6. However, it is not generally possible to conduct radiation susceptibility measurement using OATS whenever the generation of test signals is likely to interfere with existing radio broadcast or communication services or violate the frequency assignment discipline. Often, measurements made using other approaches must be validated by way of a reference to standard measurements made in an OATS. At the same time, selection and preparation of OATS require attention to details.



(a) An infinite *biconical antenna* consists of two cones of half angle θ_h with a small gap at the feed point.



(b) *Log-periodic antennas* (log-periodic array)



(c) Geometry of a typical *horn antenna*

Figure 10.11: Examples of test antennas: (a) biconical antenna, (b) log periodic antenna, (c) horn antenna

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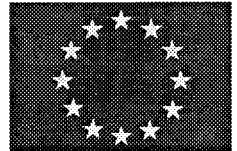
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Theory Manual

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