Internship Report

On

"EMI/EMC Testing"

by Ministry of Electronics and Information Technology

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Ministry of Electronics and Information Technology

STQC Directorate

Electronics Regional Test Laboratory (North)

New Delhi

CERTIFICATE

This is to certify that the project report entitled "**EMI/EMC Testing**" submitted by

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has been accomplished under my guidance.

This report is submitted for award of Internship Completion certificate at **Electronics Regional Test Laboratory (North), New Delhi** from 11^{th} June to 10^{th} Aug 2018 under **Digital India Internship Scheme** of **Ministry of Electronics and Information Technology** required for industrial training for completing **Bachelor of Technology in Electronics and Communication Engineering** at **Amity School of Engineering and Technology, Delhi** affiliated to **Guru Gobind Singh Indraprastha University, New Delhi.**

Date: 20/8/18

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ABSTRACT

Electromagnetic compatibility (EMC) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects (Electromagnetic Interference: EMI) that such energy may induce. EMC aims to ensure that equipment items or systems will not interfere with or prevent each other's correct operation through spurious emission and absorption of EMI. EMC is sometimes referred to as EMI Control, and in practice EMC and EMI are frequently referred to as a combined term "EMI/EMC".

Compliance with national or international standards is usually required by laws passed by individual nations. Different nations can require compliance with different standards. By European law, manufacturers of electronic devices are advised to run EMC tests in order to comply with compulsory CE-labeling. Undisturbed usage of electric devices for all customers should be ensured and the electromagnetic field strength should be kept on a minimum level.

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Chapter 1

STQC

1.1 Introduction

Standardisation Testing and Quality Certification (STQC) Directorate is an attached office of the Ministry of Electronics and Information Technology, Government of India, provides quality assurance services in the area of Electronics and IT through countrywide network of laboratories and centres. The services include **Testing, Calibration, IT and e-Governance, Training** and **Certification** to public and private organizations.

STQC laboratories are having National/International accreditation and recognitions in the area of testing and calibration.

Besides testing and calibration STQC has specialized institutions such as Indian Institute of Quality Management (IIQM) for quality related training programs. Centre for Reliability (CFR) for reliability related services and Centre for Electronics Test Engineering (CETEs) for skill based trainings.

In the area of IT and e-Governance, STQC provides assurance services through its IT Centres for Software Quality testing, Information Security and IT Service Management by conducting testing, training, audit and certifications. STQC is responsible for maintaining eGov standards. Based on this concept a Conformity Assessment Framework (CAF) for e-Governance project has also been developed and is in operation. Two IT test laboratories, at Bangalore and Kolkata, have received accreditation from American Association for Laboratory Accreditation (A2LA) being the first outside the USA.

1.2 Vision and Mission

1.2.1 Vision

Be a Quality Assurance service organization to enhance processes and competitiveness of IT and electronics industry enabling them to deliver products and services of global standards.

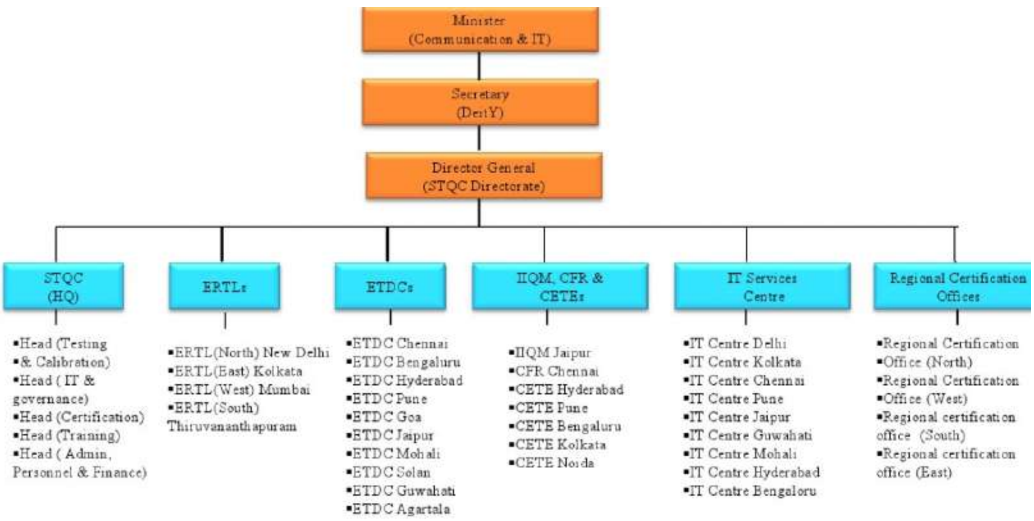
1.2.2 Mission

To support industry and trade and protect consumer interest in electronic and IT sector by providing customer centric, accredited quality assurance services as per international standard for global acceptance.

1.2.3 Objectives

- Become a key player in national measurement assurance system by providing test and calibration facilities in emerging technologies.
- Support national e-Governance Plan (NeGP) through Quality and Security evaluations of IT systems and other projects of national importance.
- Providing certification services to industry for processes and products for global compliance Enhancement of knowledge of professionals in the area of quality management and test engineering.
- Provide services in professional manner by enhancing internal efficiency.

1.3 Organisational Structure



Organization Chart of STQC Directorate

1.4 STQC Accreditations

The STQC enjoys the status of a Prime Assurance Services provider in the area of Electronics and IT in India and is represented in all the major national forums such as Bureau of Indian Standards (BIS), Quality Council of India (QCI), National Accreditation Board for Test and Calibration Laboratories (NABL) and major Industry Associations.
STQC also offers testing, calibration, training and certification services in Electronics and IT to countries like USA, UK, France, Germany, Austria, China, Singapore, Nepal, Bhutan, Taiwan, Dubai, Mauritius etc.

1.4.1 National Accreditations

- Testing & Calibration Laboratories Accredited by NABL
- BIS Accredited Test Laboratories
- Approved laboratory of DG(Mines Safety) and DG(Factory Advice Services and Labour Institutes)
- Approved laboratory of Ministry of New and Renewable Energy.
- Accredited by National Accreditation Board for Certification Bodies (NABCB), India for ISO 9000 QMS

1.4.2 International Accreditations

- Software and System Testing in conformance with international standards recognized by industry and Govt. Organizations
- STQC on behalf of India is the signatory to Common Criteria Recognition Arrangement (CCRA) with Indian Common Criteria Certification Scheme (IC3S) for evaluation and certification of IT products for security
- National Certification Body (NCB) under IECEE-CB Scheme
- Approved CB Laboratories under IECEE-CB Scheme
- Inspection Agency for VDE, KEMA, JQA, IMQ, CEBEC, LCIE
- Listing with Federal Communication Commission (FCC), USA
- Approved laboratory of UL-DEMKO and DEKRA-EXAM for testing for ATEx Certification

Chapter 2

ERTL (NORTH)

2.1 Introduction

Electronics Regional Test Laboratory (North), New Delhi, popularly known as **ERTL (N)**, is one of the flagship laboratory of STQC Directorate, Ministry of Electronics and Information Technology, Government of India, engaged primarily in providing Accredited Calibration and Testing facilities. It is one of the ERTL set up to serve small and medium scale electronic industries located in India. ERTL (North) serves the industries located in northern India with an aim of upgrading the overall quality of electronics products manufactured in India.

Electronics Regional Test Laboratory (North), ERTL(N) was formerly functioning as Test, Evaluation & Calibration Centre at the National Physical Laboratory, New Delhi before being shifted to its present location at Okhla Industrial Area in the year 1982. The laboratory is functioning under Government of India and is performing its activities, as a independent test laboratory in the field of testing, calibration, developmental assistance and training through technically trained manpower using accredited facilities. The laboratory strives to identify the customer's needs and update the facilities accordingly. The laboratory shall ensure quality of the results provided to customers by implementing checks, inter-lab comparisons and participation in proficiency testing.

2.2 Electronics and Electrical Testing

The conformances to technical specifications, quality, reliability and performance of electrical and electronics products is an important aspect for consumers as well as equipment / products manufacturers. The compliance to various national and international standards / specifications is usually carried out by testing and evaluations of such products. STQC laboratories namely ERTLs and ETDCs located through out India, in houses state of the art facilities for testing of various products as per national & international specifications. The various services in the Electronics and Electrical testing by ERTL(N) includes Component Testing, Equipment System Testing, Environmental Testing, Safety Testing, EMI/EMC Testing, Reliability Testing & Analysis and Explosive Atmosphere Compatibility Testing

2.2.1 Component Testing

STQC has created a network of third party independent component test laboratories in India. These labs have state of art facilities to test typical consumer and professional grade components to various national / International specifications. Laboratories undertake various in component testing like Type Testing, Burn IN, Screening, IECQ Certification, Acceptance testing, Environmental/Durability tests on the components.

2.2.2 Equipment System Testing

The testing and evaluation of electrical and electronic assemblies and systems is an integral part of quality assurance prior to its use. The power /energy test benches, communication test setup, environmental chambers, Anechoic chamber, Oscilloscopes, Spectrum analyzers, Precision DMMs etc. are some of the unique testing facilities at STQC laboratories.

The testing of power/ energy equipment, RF and communication equipment, Testing and measuring instruments, consumer and domestic products and computer and IT hardware products and systems equipments / instruments to carryout testing as per national and international specifications and standards.

2.2.3 Environmental Testing

All Laboratories are equipped to simulate different environmental conditions to find out the effects on Product/ Component performance. Environmental conditions such as high temperature, low temperature, humidity, corrosion, low air pressure, vibration, Impact (both repetitive and non-repetitive) can be simulated in the laboratories as per requirements of standards like IS, JSS, MIL, IEC etc. Multivariate environment to simulate real life usage conditions can be obtained from the wide inventory of Chambers possessed by the Laboratories. Test evaluation of products/Components can be done for Vibrations, Bump, Shock, Drop, Topple, Salt spray, Splash and rain. Testing for the Ingress Protection for Water and Dust can also be taken up. Highly accelerated testing Technologies (HAST: Highly accelerated Temperature and Humidity Stress) in terms of various combination of temperature and Humidity up to 175 degree Celsius and 100% RH with Gauge pressure up to 4 bar to reduce testing time is also available.

2.2.4 Safety Testing

Safety testing of various Electrical/Electronic appliances/equipment has become of great importance specially in mission critical applications and safety critical components. The product design for safety aspects of products shall be safe to use in normal and abnormal condition i.e. it does not only provide the protection of human beings against injuries or safeguard against health hazards but also the protection of property and environment in connection with the operation of equipment, installation and process. An electronic /electrical product must provide protection against following safety hazards namely Electric shock, Harmful radiation, Excessive Temperature, Implosion, Mechanical instability, Fire etc. STQC laboratories houses safety testing facilities as per national & international specifications.

2.2.5 EMI/EMC Testing

Increased pollution in the form of EMI/RFI and other spurious signals created in some part by some of sophisticated Equipment/Component and radiated by interconnecting cables may create malfunction in TV, Radio, Computers, Airways Communications, Medical Equipment etc. Testing of the products for the EMI regulations is necessary in most of the countries. All the products need to be constructed so that it does not cause interference and in particular, does not interfere with radio and telecommunication equipments further, equipment must have an intrinsic immunity level to electromagnetic disturbances, which will enable it to operate as intended.Capability of an individual product to meet the EMC requirements can be verified by testing the product against laid out standards at our Laboratories. Products Covered: Industrial, Scientific, Medical, Automotives, Broadcast receivers, Household Appliances/Tools, Fluorescent Lights/Luminaries, Measuring Apparatus, Information Technology Equipment etc.

2.2.6 Reliability Tesing and Analysis

Reliability analysis of Electrical, Electronics and IT products plays an important role in R&D and manufacturing of reliable products. The products manufactures require reliability analysis so as to improve the reliability of products and systems. Keeping in view STQC has established Center For Reliability (CFR) located at Chennai. The CFR Chennai has also developed Software tools for Reliability Engineering. These tools are in use in more than 300 organizations in India and Abroad.

2.2.7 Explosive Atmosphere Compatibility Testing

The facility was initially set up in 1989 under the aegis of Indo-German Technical Co-operation Programme, which provided equipment and knowledge inputs. The laboratory contributed significantly to the development of Indian Standards for Mining Electronic products and is currently a member of the ET-22 Committee of the Bureau of Indian Standards. The facilities cover testing of a wide range of Electronic / Electrical products for use in hazardous atmospheres as per IS, EN and IEC standards. The present capability covers protection techniques flameproof, intrinsic safety, increased safety, pressurized and encapsulated.

2.2.8 Specialized Services offered by ERTL(N)

- High Precision Calibration Centre
- On-site Test and Calibration Services
- 3m Anechoic Chamber
- GTEM Cell upto 3 GHz
- 10m OATS (Open Area Test Site) for EMI/EMC

- Combined Environmental Test Chamber with Vibration Test System, 5000 kgf
- Climatic Walk in Test Chamber
- Precision Temperature and Resistance Calibration (PTRC)

To ensure the degree of equivalence, this laboratory is participating in Inter-laboratory comparison programmes. All of our calibration facilities are NABL accredited.

2.3 ERTL(N) Recognitions and Accreditations

2.4 National

- By BIS for Safety Testing of electronic products as per Electronics and Information Technology Goods (Requirements for Compulsory Registration) Order, 2012 of Ministry of Electronics and IT and Extra-ordinary Gazette notification Part II Section 3 - Sub-section (ii) dated Oct.,3,2012.The electronic products include video games, laptop/notebook/tablet, Plasma/LCD/LED televisions of screen size 32 and above, Set Top Boxes, Printers, Plotters, Scanners, Wireless Keyboards, Telephone Answering Machines, Electronic Musical Systems etc. as per relevant specifications IS 616:2010, IS 13252:2010 and IS 302-2-26:1994.
- By NABL for Testing and Calibration in the field of Electronics, Electro-technical and Non-Electrical (Mass, Temperature & Dimension) disciplines, by STQC for "S" Mark and EMC Certification, BIS recognition for AC static Energy Meters, Capacitors, Electronic Ballast, Voltage Stabilizers, CFL, Inverter, Automatic Voltage Corrector and Electronic fan regulators.

2.5 International

- NSI Laboratory under IECQ System, CB Test Laboratory under IECEE-CB Scheme, EMI/EMC Testing by FCC (USA), Testing for EMI/EMC under telecommunication. Certification Body Program, Testing for Safety of Electronics/Electrical products by SASO, SONCAP, Membership of NCSL. Testing of equipment for CE marking under self declaration for manufacturers interested in export to Europe.

Chapter 3

EMI/EMC

3.1 Introduction

A passenger jet explodes in mid-air killing all 230 people on board. A hospital syringe pump spontaneously ceases its delivery of life-preserving medication without triggering any alarms. A nuclear power plant goes on alert status when turbine control valves spontaneously close. Each of these actual events was a symptom of an electromagnetic compatibility problem.

In 1996, TWA Flight 800 bound from New York to Paris exploded over the ocean shortly after take-off. After a lengthy investigation that involved salvaging and reconstructing major portions of the aircraft, it was concluded that the most probable cause of the explosion was a spark in the center wing fuel tank that ignited the air/fuel mixture. This spark was likely the direct result of a large voltage transient, possibly a power line transient or electrostatic discharge. In 2007, the results of a study conducted by researchers at the University of Amsterdam documented nearly 50 incidents of electromagnetic interference from cell phone use in hospitals and classified 75 percent of them as significant or hazardous. Another study, published in 2008 by researchers from Amsterdam, showed that electromagnetic interference from RFID devices also had the potential to cause critical care medical equipment to malfunction.

Spontaneous valve closures at the Niagara Mohawk Nine Mile Point #2 nuclear power plant were due to interference generated by workers' wireless handsets. Despite the tremendous emphasis on safety and security that is placed on the design and construction of all nuclear power plants, the relatively weak emissions from common wireless handsets resulted in a major malfunction.

Unfortunately, these are not rare isolated occurrences. Electromagnetic compatibility problems result in many deaths and billions of dollars in lost revenue every year. The past decade has seen an explosive increase in the number and severity of EMC problems primarily due to the proliferation of microprocessor controlled devices, high frequency circuits and low power transmitters.

3.2 EMI

Electro Magnetic Interference (EMI) is the generic term describing a situation whereas an electrical disturbance generated by a certain electronic/electrical equipment is causing an undesirable response to another equipment. This undesirable effect may range from a mere nuisance to a catastrophic failure, with associated financial losses or eventually human casualties. The origin of the disturbance could also be a natural phenomena like lightning strokes or ElectroStatic Discharges (ESD). The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data. EMI frequently affects AM radios. It can also affect mobile phones, FM radios, and televisions, as well as observations for radio astronomy. Each system must be compatible with itself, other systems, and external environment to ensure required performance and to prevent costly redesigns for the resolution of problems. External to the system are electromagnetic effects such as lightning, electromagnetic pulse (EMP), electrostatic discharge and man-made RF transmissions. Internal to the system are electromagnetic effects such as electronic noise emissions, self-generated RF transmissions from antennas, and cross coupling of electrical currents.

EMI can be used intentionally for radio jamming, as in electronic warfare.

3.2.1 Types of Interference

Electromagnetic interference divides into several categories according to the source and signal characteristics. The origin of noise can be man made or natural.

Continuous Interference

Continuous interference arises where the source regularly emits a given range of frequencies. This type is naturally divided into sub-categories according to frequency range, and as a whole is sometimes referred to as “DC to daylight”. Audio Frequency, from very low frequencies up to around 20 kHz. Frequencies up to 100 kHz may sometimes be classified as Audio. Sources for continuous interference include:

- Mains hum from power supply units, nearby power supply wiring, transmission lines and substations.
- Audio processing equipment, such as audio power amplifiers and loudspeakers.
- Demodulation of a high-frequency carrier wave such as an FM radio transmission.
- Radio Frequency Interference (RFI), from typically 20 kHz to an upper limit which constantly increases as technology pushes it higher.

Transient Interference

Electromagnetic Pulse, also sometimes called Transient disturbance, arises where the source emits a short-duration pulse of energy. The energy is usually broadband by nature, although it often excites a relatively narrow-band damped sine wave response in the victim. Sources divide broadly into isolated and repetitive events. Sources of isolated EMP events include:
- Switching action of electrical circuitry, including inductive loads such as relays, solenoids, or electric motors.
- Electrostatic Discharge (ESD), as a result of two charged objects coming into close proximity or even contact.
- Lightning Electromagnetic Pulse (LEMP), although typically a short series of pulses.
- Nuclear Electromagnetic Pulse (NEMP), as a result of a nuclear explosion.
- Non-Nuclear Electromagnetic Pulse (NNEMP) weapons.
- Power Line Surges/Pulses
- Electric Motors
- Continual switching actions of digital electronic circuitry.

3.2.2 EMI Control

To control or suppress EMI, the three common means employed in the design process are Grounding, Shielding and Filtering.

Grounding

Grounding is the establishment of an electrically conductive path between two points to connect electrical and electronic elements of a system to one another or to some reference point, which may be designated as the ground. An ideal ground plane is a zero-potential ,zero-impedance body that can be used as a reference for all signals in associated circuitry and to which any undesired current can be transferred for the elimination of its effects.

Shielding

The purpose of shielding is to confine radiated energy to a specific region or to prevent radiated energy from entering a specific region. Shields may be in the form of partitions and boxes as well as in the form of cable and connector shields. Shield types include solid, nonsolid (e.g., screen), and braid, as is used on cables. In all cases, a shield can be characterized by its shielding effectiveness. The shielding effectiveness is defined as

$$Sheilding\,Effectiveness \;=\; 10\log\frac{Incident\,Power\,Density}{Transmitted\,Power\,Density}$$

where the incident power density is the power density at a measuring point before a shield is installed and the transmitted power is the power density at the same point after the shield is in place.

Filtering

An electrical filter is a network of lumped or distributed constant resistors, inductors, and capacitors that offers comparatively little opposition to certain frequencies, while blocking the passage of other frequencies. Filter provides the means whereby levels of conducted interference are substantially reduced. The most significant characteristic of a filter is the insertion loss it provides as a function of frequency. Insertion loss is defined as

$$Insertion\,Loss \;=\; 20\log\frac{V2}{V1}$$

Where V1 is the output voltage of a signal source with the filter in the circuit, and V2 is the output voltage of the signal source without the use of the filter.

3.3 EMC

Electromagnetic compatibility (EMC) is the branch concerned with the unintentional generation, propagation and reception of electromagnetic energy which may cause unwanted effects such as electromagnetic interference (EMI) or even physical damage in operational equipment. The goal of EMC is the correct operation of different equipment in a common electromagnetic environment.

EMC pursues three main classes of issue. **Emission** is the generation of electromagnetic energy, whether deliberate or accidental, by some source and its release into the environment. EMC studies the unwanted emissions and the countermeasures which may be taken in order to reduce unwanted emissions. **Susceptibility** is the tendency of electrical equipment, referred to as the victim, to malfunction or break down in the presence of unwanted emissions, which are known as Radio frequency interference (RFI). Immunity is the opposite of susceptibility, being the ability of equipment to function correctly in the presence of RFI, with the discipline of "hardening" equipment being known equally as susceptibility or immunity. **Coupling** which is the mechanism by which emitted interference reaches the victim.

Interference mitigation and hence electromagnetic compatibility may be achieved by addressing any or all of these issues, i.e., quieting the sources of interference, inhibiting coupling paths and/or hardening the potential victims. In practice, many of the engineering techniques used, such as grounding and shielding, apply to all three issues.

3.3.1 EMC Control

The damaging effects of electromagnetic interference pose unacceptable risks in many areas of technology, and it is necessary to control such interference and reduce the risks to acceptable levels.Assurance of EMC comprises a series of related disciplines like characterising the threat, setting standards for emission and susceptibility levels, design and testing for standards compliance

Characterising the Threat

Characterisation of the problem requires understanding of:
- The interference source and signal.
- The coupling path to the victim.
- The nature of the victim both electrically and in terms of the significance of malfunction.
- The risk posed by the threat is usually statistical in nature, so much of the work in threat characterisation and standards setting is based on reducing the probability of disruptive EMI to an acceptable level, rather than its assured elimination.

EMC Design

Electromagnetic noise is produced in the source due to rapid current and voltage changes, and spread via the coupling mechanisms described earlier.

Since breaking a coupling path is equally effective at either the start or the end of the path, many aspects of good EMC design practice apply equally to potential emitters and to potential victims. Further, a circuit which easily couples energy to the outside world will equally easily couple energy in and will be susceptible. A single design improvement often reduces both emissions and susceptibility.

Grounding and Shielding

- Grounding and shielding aim to reduce emissions or divert EMI away from the victim by providing an alternative, low-impedance path. - Grounding or earthing schemes such as star earthing for audio equipment or ground planes for RF. The scheme must also satisfy safety regulations.

- Shielded cables, where the signal wires are surrounded by an outer conductive layer that is grounded at one or both ends. Shielded housings. A conductive metal housing will act as an interference shield. In order to access the components, such a housing is typically made in sections (such as a box and lid); an RF gasket may be used at the joints to reduce the amount of interference that leaks through the joint. RF gaskets come in various types.

- Decoupling or filtering at critical points such as cable entries and high-speed switches, using RF chokes and/or RC elements. A line filter implements these measures between a device and a line.

Emissions Suppression

-Avoid unnecessary switching operations. Necessary switching should be done as slowly as is technically possible.

-Noisy circuits (with a lot of switching activity) should be physically separated from the rest of the design.

-High peaks can be avoided by using the spread spectrum method, in which different parts of the circuit emit at different frequencies.

-Harmonic wave filters.

-Design for operation at lower signal levels, reducing the energy available for emission.

Susceptibility hardening

-Fuses, trip switches and circuit breakers.

-Transient absorbers.

-Design for operation at higher signal levels, reducing the relative noise level in comparison.

-Error-correction techniques in digital circuitry. These may be implemented in hardware, software or a combination of both.

-Differential signaling or other common-mode noise techniques for signal routing.

3.3.2 Coupling Mechanism of Interference

There are four basic coupling mechanisms: conductive, capacitive, magnetic or inductive, and radiative. Any coupling path can be broken down into one or more of these coupling mechanisms working together.

Conductive Coupling

Conductive coupling occurs when the coupling path between the source and the receptor is formed by direct contact with a conducting body, for example a transmission line, wire, cable, PCB trace or metal enclosure.

Inductive Coupling

Inductive coupling occurs where the source and receiver are separated by a short distance (typically less than a wavelength). Strictly, "Inductive coupling" can be of two kinds, electrical induction and magnetic induction. It is common to refer to electrical induction as capacitive coupling, and to magnetic induction as inductive coupling.

Capacitive Coupling

Capacitive coupling occurs when a varying electrical field exists between two adjacent conductors typically less than a wavelength apart, inducing a change in voltage across the gap.

Magnetic Coupling

Inductive coupling or magnetic coupling (MC) occurs when a varying magnetic field exists between two parallel conductors typically less than a wavelength apart, inducing a change in voltage along the receiving conductor. **Radiative Coupling**

Radiative coupling or electromagnetic coupling occurs when source and victim are separated by a large distance, typically more than a wavelength. Source and victim act as radio antennas: the source emits or radiates an electromagnetic wave which propagates across the open space in between and is picked up or received by the victim.

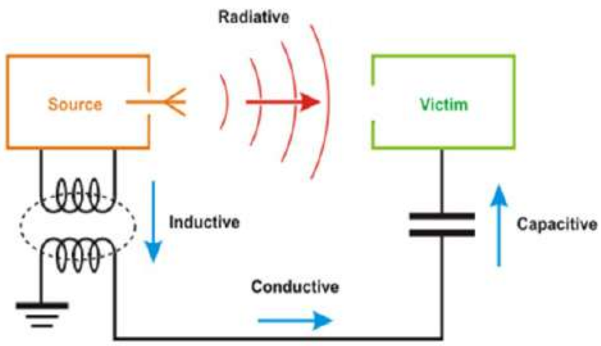


Figure 3.1: Coupling Mechanisms of RF Noise

Chapter 4

EMI/EMC Testing

4.1 Introduction

EMC (ElectroMagnetic Compatibility) testing exists to ensure that your electronic or electrical device doesn't emit a large amount of electromagnetic interference (known as radiated and conducted emissions) and that your device continues to function as intended in the presence of several electromagnetic phenomena.

Regulatory bodies around the world have placed limits on the levels of emissions that electronic and electrical products can generate.

Also, electromagnetic immunity testing is mandated for some areas and some product types. In the first chapter of this guide, we'll be digging into the applicability of emissions and immunity tests to your product, as well as determining exactly which standards apply. Generally speaking, EMC can be grouped into two categories:

- Immunity Testing - measures how a device will react when exposed to electromagnetic noise and other disturbances. The purpose of these tests is to gain a reasonable assurance that the device will operate as intended when used within its expected operating environment.

- Emissions Testing - measures the amount of electromagnetic noise generated by a device during normal operation. The purpose of these tests is to ensure that any emission from the device are below the relevant limits defined for that type of device. This, in turn, provides a reasonable assurance that the device will not cause harmful interference to other devices operating within its expected operating environment.

Regulatory compliance and due diligence require that electronic devices undergo one or both types of testing. The most common applications for EMC/EMI testing are:

- Medical Devices - EMC testing is critical for managing risk in medical device manufacturing. Devices must be able to work together in close environments without interference or noise compromising performance. The FDA requires that all medical devices undergo EMC testing per the appropriate FDA Reviewer Guidance document or the European IEC 60601-1-2 standards. In the EU, all medical devices must have CE marking, which requires both immunity and emissions testing per IEC 60601-1-2.

- Military/Aerospace Devices - MIL-STD-461 outlines EMC testing requirements for military equipment, including electromagnetic susceptibility and emissions testing. MIL-STD-461 contains relatively stringent electromagnetic compatibility requirements. Devices which are compliant with MIL-STD-461 are typically well-positioned to meet FCC, DO-160 and other standards for avionics equipment, consumer goods and other products.

- Consumer Goods - Consumer goods such as microwave ovens, cellular phones, laptops and satellite TV dishes all must undergo EMC/EMI testing to ensure they do not cause harmful interference and accept interference without causing undesired operation in real-world conditions. For more information about EMC/EMI testing for different devices, contact Com-Power Corporation directly.

Repeatability is very important for all types of EMC testing and proper test setup is always the key to achieve a good repeatability.

4.2 Quasi Peak

Quasi-peak means 'not quite peak', or 'aiming towards peak but not actually peak'. This was originally done because the quasi-peak detector was believed to better indicate the subjective annoyance level experienced by a listener hearing impulsive interference to an AM radio station.

Most radiated and conducted limits in electromagnetic compatibility (EMC) testing 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." They do this by having a charge rate much faster than the discharge rate. Therefore as the repetition rate increases, the quasi-peak detector does not have enough time to discharge as much, resulting in a higher voltage output (response on spectrum analyzer). For continuous wave (CW) signals, the peak and the quasi-peak response are the same. 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.

Quasi-peak detector readings will always be less than or equal to the peak detection. Because quasi-peak readings are much slower, (by 2 or 3 orders of magnitude compared with peak) it is very common to scan initially with the peak detection first, and then if this is marginal or fails, switch and run the quasi- peak measurement against the limits.

4.3 Types of Noise

4.3.1 Differential Mode Noise

Looking at conducted signals, noise can occur between any two lines of system. In a single phase system, this could be between phase (P) and neutral (N) line. In a three phase system it could be phase 1 (R) and phase 2 (S). In Dc systems noise can travel from plus to minus. Such noise is called Differential Mode or Symmetrical Noise. The picture shown below shows differential mode noise in a single phase system. Differential mode noise is a result of parasitic component in a circuit, such as equivalent series inductance or equivalent series resistance or component. In an electronic system the differential mode noise occurs at lower frequencies and is commonly associated with the switching frequency of a switched mode power supply or motor drive.

4.3.2 Common Mode Noise

Noise can also be conducted from any line in the system towards earth. In a single phase system, a signal can go from L and P towards earth. This type of noise is called common mode noise. The main difference is that the common mode noise travels in all lines in the same direction and then comes towards earth. The picture below shows the common mode signals in a single phase system. Common mode noise results from stray capacitances in a system, often occurring between semiconductors and heat sink. Common mode noise more often occurs at higher frequency range. When we look at the measurements it is very much difficult to make the differentiation between the two types of noises. For noise suppression however, it is crucial to understand what kind of noise we are dealing with.

4.4 Emission Test

4.4.1 Conducted Emission

Conducted emissions **(CE)** are the noise currents generated by the Device-Under-Test (DUT) that propagate through the power cord or harness to other components/systems or power grid. These noise currents can be measured using either the voltage method or the current method. CE measurement applies to AC, DC, signal and telecommunication ports of all types of electronics products. The standards generally set the conducted RF range from 150 KHz to 30 MHz. Some standards also starts from lower frequency of 9Khz. This helps to ensure that the local power supply remains relatively 'clean' and nearby devices won't be affected by DUT. The requirements for CE measurements are:
- Line and impedance stabilizing networks (LISNs).
- Measuring receivers with Average and CISPR detector.
- Auxiliary measuring equipment.

Line and impedance stabilizing networks (LISNs) serves following functions:
- Provides stable Line Impedance as a function of frequency on the power line.
- Prevent External Noise (from the power line) getting coupled to the EUT.
- Provide an RF noise measurement port (50 ohm).

Thus LISN is very essential for conducted emmission measurement.

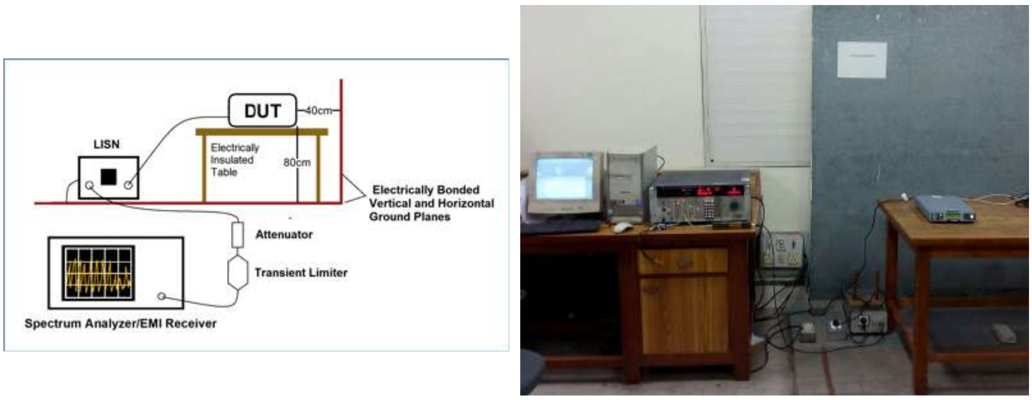


Figure 4.1: Setup for Conducted Emission Test

Physical Setup

- Place the DUT in the center of a non-conductive table.
- Place the horizontal ground plane 80 cm and center just below the DUT.
- Place the vertical ground plane 40 cm behind and centered with the DUT

having electrical bond to the horizontal ground plane.
- Electrically bond the LISN to the horizontal ground plane using the LISN bonding strap.
- Place the spectrum analyzer/EMI receiver a few feet from the edge of the horizontal ground plane/test area and connect it to a power source.

Test Measurement

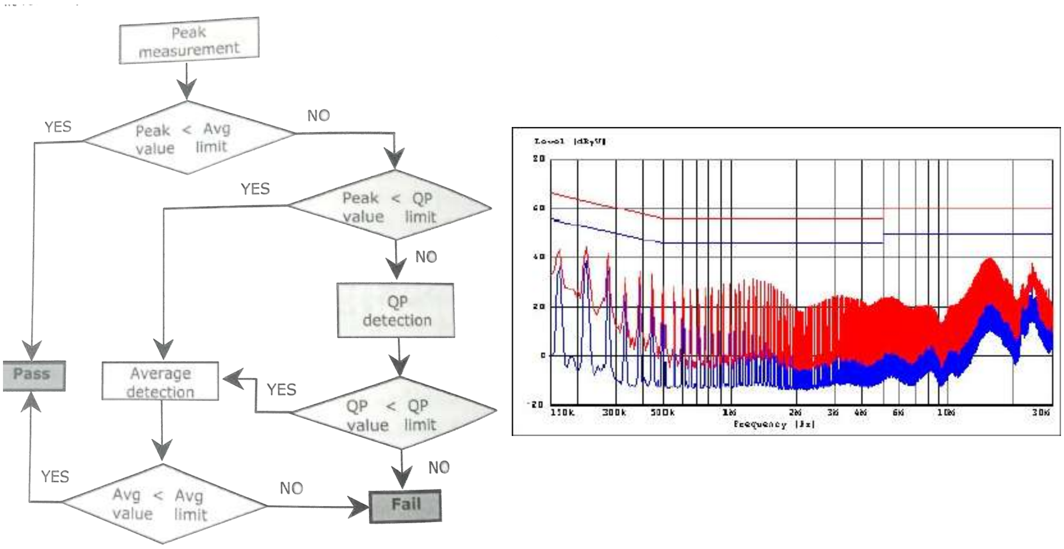


Figure 4.2: Graph and Flowchart for measurement

4.4.2 Radiated Emission

Radiated emissions testing is designed to identify signals emitted into space from a device under test, typically at frequencies from 30 to 1000 MHz. However, measurements can be performed at much higher frequencies. Some people will need to measure above 1GHz, for example for some types of radiofrequency (RF) equipment when applying EN 55011 (CISPR11), or when meeting FCC requirements for the USA with a product containing a clock of over 108MHz. Some people need to measure below 30MHz, for example when measuring cable TV distribution systems. Military radiated emissions testing also covers a much wider range than 30MHz to 1GHz.

Radiated emissions testing involves measuring the electromagnetic field strength of the emissions that are unintentionally generated by your product. The electromagnetic waves don't extend out from your product in a nice spherical pattern. The emissions tend to be pretty directional, so a test lab has to vary the height of the receiving antenna between 1 and 4 meters as well as rotate a turntable. The receiving antenna picks up both the signal direct from the EUT, as well as a bounce off the ground. To increase measurement accuracy, the ground is covered with an electromagnetically reflective surface (aluminum, steel, wire mesh etc..) and this ground plane must be relatively flat. The test lab will scan the frequency band of interest and look for emissions that are close to the limits.

For carying out such testing a specialised two basic techniques are used. An EUT is Kept at 3-10 Meter distance on a turntable from the measuring antenna whose height can be varied from 1-4 meters. This is done to acheive the maximum radiation being emitted from the EUT. Types of methods to conduct RE tests are done in

1. Open Area Test Site (OATS)
2. Anechoic chamber

Open Area Test Site

The traditional, and current reference, test site for conducting radiated emissions measurements is an open area test site. Due to the abundance of such sites, a majority of radiated emissions compliance testing is still performed at these sites. The rising popularity of cellular phones, wireless PDAs, Blackberrys, HDTV signals, satellite transmissions and overall expanded use of additional radio frequency bands, continue to make it increasingly difficult to conduct emissions tests using OATS because of the increased presence of these ambient emissions.

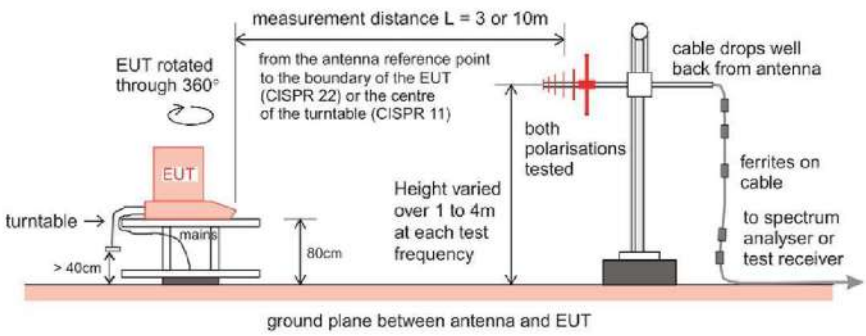


Figure 4.3: A layout for Open Area Test Site

An ideal open area test site is defined as a perfectly flat, infinitely large, continuous ground plane having infinite conductivity and located in free space. The term free space is defined as an open area, free of objects which can reflect electromagnetic waves including buildings, electric lines, fences, trees, hills etc. Obviously, there are no sites in the world that are “ideal since most OATS will have some degree of imperfection, although most test sites strive to be as near to ideal as possible.

The original OATS construction was an uncovered ground plane. As laboratories strived to test in all weather environments OATS were either retrofitted or constructed with partial and/or full coverings. These coverings allow laboratories to test in weather that in an unprotected environment would not be feasible.

Anechoic Chamber

An Anechoic chamber, is just like an OATS, only it's housed within a shielded (metal) room. This is really helpful because it attenuates the background (ambient) radio signals, so it's much easier to distinguish what's coming from your product vs. the background signals. The inside of a Anechic Chamber is lined with RF absorber material so that reflected signals are kept to a minimum. Without these absorbers, the measurement antenna would receive an unquantifiable signal contribution from wall and ceiling reflections, making the measurements quite inaccurate. Chambers are quite expensive, but they are a good solution to measuring EMI in a noisy environment.

The distance between the antenna and the equipment under test (EUT) is typically 3m or 10m. The measurement distance is important because we want to ensure that we are measuring the field strength in the far field as opposed to near field. At 30 MHz, the wavelength is 10m. As we approach the near field or fresnel region (region between near and far field), the electric field may not yet be stable and the measurements will be less accurate.

Figure 4.4: An Anechoic Chamber

Anechoic Chambers are categorised as Full Anechoic Chamber (FAC) or Semi Anechoic Chamber (SAC) on the basis of number of RF absorbing surfaces in the chamber. Full anechoic chambers aim to absorb energy in all directions. Semi-anechoic chambers have a solid floor that acts as a work surface for supporting heavy items, such as cars, washing machines, or industrial machinery, rather than the mesh floor grille over absorbent tiles found in full anechoic chambers. This floor is damped and floating on absorbent buffers to isolate it from outside vibration or electromagnetic signals.

A separate Measurement Chamber is required in order to take the measurement as the Spectrum Analyzer/EMI Receiver can't be placed in the same room as the EUT as the emission pattern may be effected by human or other device's presence. The receiver can't be kept in open either as the interconnecting probe cables are very sensitive and may peak radiation present in environment making the measurement obsolete. Hence, the Measurement Chamber provides an isolated environment for the receiver as well.

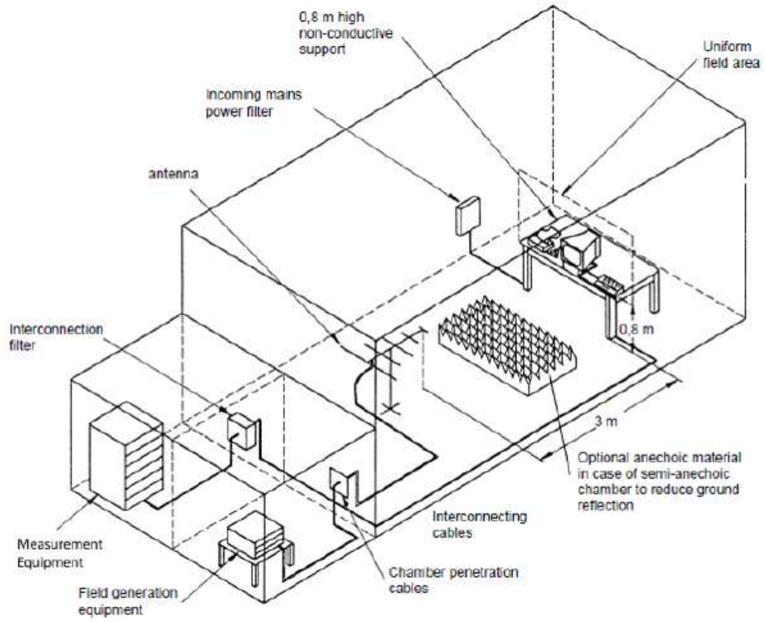


Figure 4.5: A layout for RE measurement in anechoic chamber

Same procedure is followed in Radiated Emission Test also. Here also we obtain same type of graphs as Conducted Emission and check for either Peak, Average or Quasi Peak as per requirements in the frequency range 30 Mhz to 3 Ghz.

Figure 4.6: Bi-Conical, Log-Periodic and Horn Antenna

Various types of antenna are used to cover this broad range of frequency from 30 Mhz to 1GHz (expendable upto 18 Ghz). Bi-Conical antennas are used in the frequency range of 30 Mhz to 200 Mhz, Log-Periodic antennas are used in the frequency range of 200 Mhz to 1 Ghz and Horn antennas are used beyond 1 Ghz.

4.4.3 Harmonics and Flickering Test

'Harmonics' as defined by EMC standards refers to harmonics of the 50 or 60Hz mains supply that are imposed on the current drawn from the supply by the product. Non linear loads connected to the public power supply generate harmonic and interharmonic currents which are transmitted throughout the power network to other equipment. Mains networks are also used to transmit control and monitoring signals. It is necessary to ensure that these unwanted frequency components do not cause disruption to control or measurement units.

The increasing use of electronic equipment fitted with switch mode power supplies has led to an increase in distortion of the public power supply. Such loads draw non sinusoidal current, which contains harmonic frequencies at multiples of the 50Hz and 60Hz supply frequencies. This can lead to significant currents flowing in the neutral conductor resulting in cable and transformer overheating. This is also known as "phantom power" because it has to be transported through cables and transformers, but is not useful. Most products do cause these 'harmonics' and even though the amount created by each product may be small, the overall effect of many 1,000s on the local electricity supply network causes problems.

The EMC Directive now includes limits on harmonics which are mandatory on all products connected to the public mains supply. The standard for products rated at up to 16A/phase is IEC61000-3-2. The AC2000A is fully compliant with this standard and will provide all the measurements necessary to complete the compliance assessment. The Harmonics standard includes a requirement for the incoming mains to be itself free from harmonic content ($< 0.1\% THD$) as this may otherwise affect the accuracy of any measurements. The AC1000A is a clean power source that will provide a pure sine wave with the required low THD for loads up to 1kW.

This same instrument, also includes flicker measurements as required by IEC61000-3-3, to include inrush current measurement. Small variations in the mains supply voltage, caused by fluctuating currents interacting with the mains impedance, influence the light intensity of an incandescent bulb. Light intensity fluctuates as a square of the RMS voltage. These cyclic fluctuations called “flicker” are not noticed by the human eye but are registered by the brain, causing annoyance and increased stress. Power factor correction is a simple means of reducing flicker.

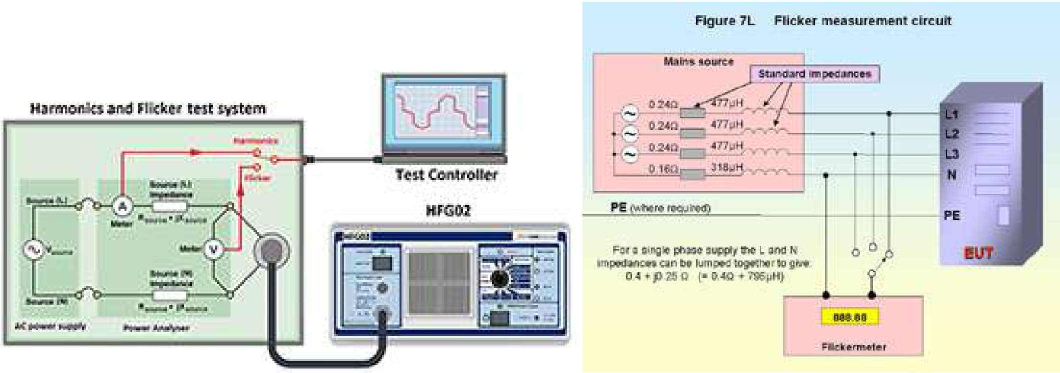


Figure 4.7: Harmonicss and Flicker Test and Graphs

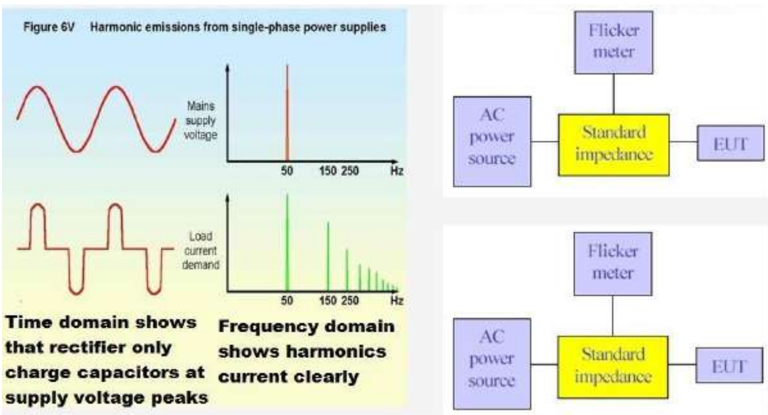


Figure 4.8: Harmonics and Flicker Measurement

4.5 Immunity Test

Conducted Susceptibility

The conducted susceptibility is performed to determine a device’s ability to operate in the presence of an external interference signal propagated via a conductor. This method is used to determine whether equipment is susceptible to external electromagnetic energy injected on its power leads, antenna ports, and interconecting cables. This test may be assumed as the reverse of the Conducted Emission test.

The source of disturbance covered by this test is basically an electromagnetic interference, coming from intended RF transmitters, that may act on the whole length of cables connected to an installed equipment. The dimensions of the disturbed equipment, mostly a sub-part of a larger system, are assumed to be small compared with the wavelengths involved. The in-going and out-going leads: e.g. mains, communication lines, interface cables, behave as passive receiving antenna networks because they can be several wavelengths long.

Between those cable networks, the susceptible equipment is exposed to currents flowing "through" the equipment. Cable systems connected to an equipment are assumed to be in resonant mode ($l/4, l/2$ open or folded dipoles) and as such are represented by coupling and decoupling devices having common-mode impedance or 150 Ohms with respect to a ground reference plane.

The EUT is subjected to an electromotive force (e.m.f.) of 3 V or 10 V from 150 kHz to 80 MHz. This frequency range is 80% amplitude modulated with a 1 kHz sine wave. The signal generator provides the modulated frequency at a step rate of 1% of fundamental to the RF amplifier. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond. Clamp injection on all cables of the EUT is used to couple the e.m.f. to the EUT.

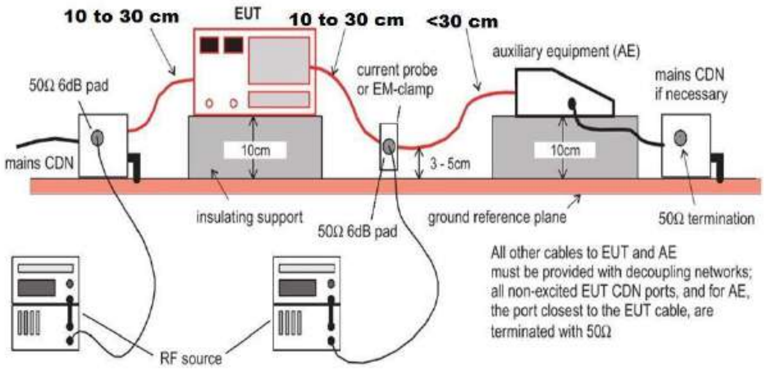


Figure 4.9: Condcucted Susceptibility

Interfering signals are nearly always differential at the terminals of the victim circuitry; however, most field to cable coupling induces common-mode voltages. A common-mode to differential-mode conversion may occur due to unbalanced circuitry or parasitic elements that produce essentially unbalanced impedances at the victim terminal.

If the EUT is affected by the susceptibility test signal, it is necessary to determine the threshold of susceptibility. At the frequency of interference, lower the signal amplitude until the indication of susceptibility is not present. Reduce the signal an additional 6 dB then Gradually increase the amplitude until the indication of susceptibility reoccurs. This is the threshold of susceptibility. Record the threshold level and the indication of susceptibility.

4.5.1 Radiated Susceptibility

The Radiated Susceptibility (RS) test is performed to determine a device's ability to operate in the presence of an external interference signal propagated via free space. Most electronic equipment is, in some manner, affected by electromagnetic radiation. This radiation is frequently generated by such sources as the small hand-held radio transceivers that are used by operating, maintenance and security personnel, fixed-station radio and television transmitters, vehicle radio transmitters, and various industrial electromagnetic sources.

In recent years there has been a significant increase in the use or radio telephones and other radio transmitters operating at frequencies between 0.8 GHz and 3 GHz. Many of these services use modulation techniques with a non-constant envelope (e.g. TDMA).

In addition to electromagnetic energy deliberately generated, there is also spurious radiation caused by devices such as welders, thyristors, fluorescent lights, switches operating inductive loads, etc. For the most part, this interference manifests itself as conducted electrical interference and, as such, is dealt with in other standards. Methods employed to prevent effects from electromagnetic fields will normally also reduce the effects from these sources.

The electromagnetic environment is determined by the strength of the electromagnetic field (field strength in volts per meter). The field strength is not easily measured without sophisticated instrumentation nor is it easily calculated by classical equations and formulae because of the effect of surrounding structures or the proximity of other equipment that will distort and/or reflect electromagnetic waves.

The EUT is subjected to a field strength of 3 V/m or 10 V/m or as per standard, from 80 MHz to 1000 / 3000 / 6000 MHz. This frequency range is 80% amplitude modulated with a 1 kHz sine wave. The signal generator provides the modulated frequency at a step rate of 1% of fundamental to the RF amplifier. The EUT is also subjected to a pulsed 900 MHz field at 200 Hz. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond. The RF amplifier provides the necessary power to the antenna to establish the field levels as monitored by the field probe or power monitor. The anechoic chamber is calibrated according to the criteria as per EN 61000-4-3 for 16 points. The antenna is positioned 3 meters from all four faces of the EUT and is oriented in horizontal and vertical polarization. In general, RS test are done in

1. An Anechoic Chamber
2. A GTEM Cell

Radiated Susceptibility Test in Anechoic Chamber

For performing RS in an anechoic chamber same setup is used except the EMI receiver is replaced with RF field generator setup for creating a RF field in the chamber using the same antennas. Additionally, the EUT is observed from the Measurement Chamber with the help of an optical camera.

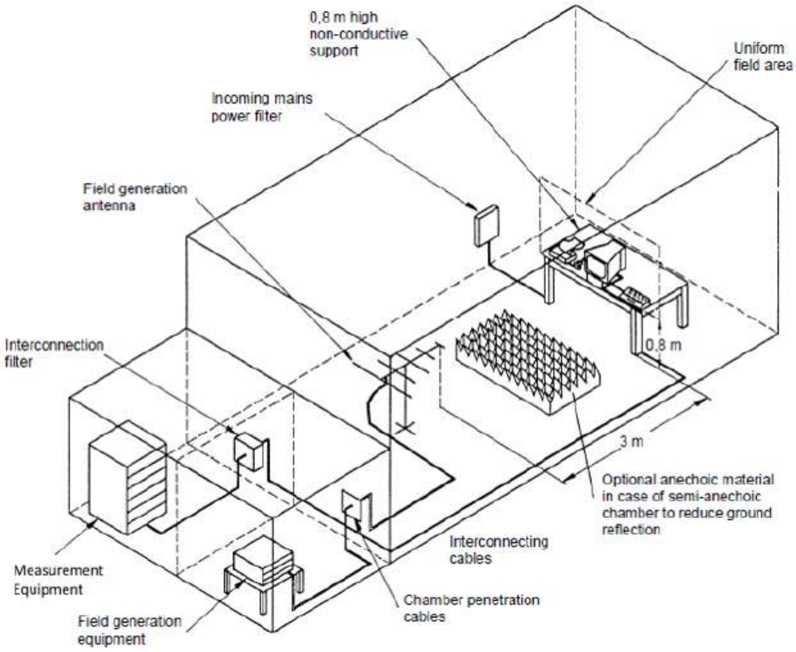


Figure 4.10: Layout for Radiated Susceptibility Test in Anechoic Chamber

Radiated Susceptibility Test in GTEM Cell

A GTEM (Gigahertz Transverse Electro Magnetic) cell is a test site for efficiently performing radiated susceptibility testing in a single, controllable and shielded environment. A GTEM cell enclosure is made of conductive material such as metal, in the shape of a long, rectangular pyramid. The pyramid is normally laid flat on one side, although occasionally it may be stood on its base. The base is typically lined internally with radiation-absorbent material (RAM), but the side walls are left bare to act as a waveguide. A stripline conductor, known as the septum, connects internally between the input/output port at the apex and a resistive RF absorber or load at the base. In operation, the equipment under test is placed in the test volume in between the septum and the chassis.

The GTEM cell forms an enclosed TEM (transverse electromagnetic mode) stripline, which acts as receiving emissions or transmitting emissions antenna. When performing radiated immunity, one end of the stripline is connected to a source of radiation (signal generator). The other end is terminated with an RF load.

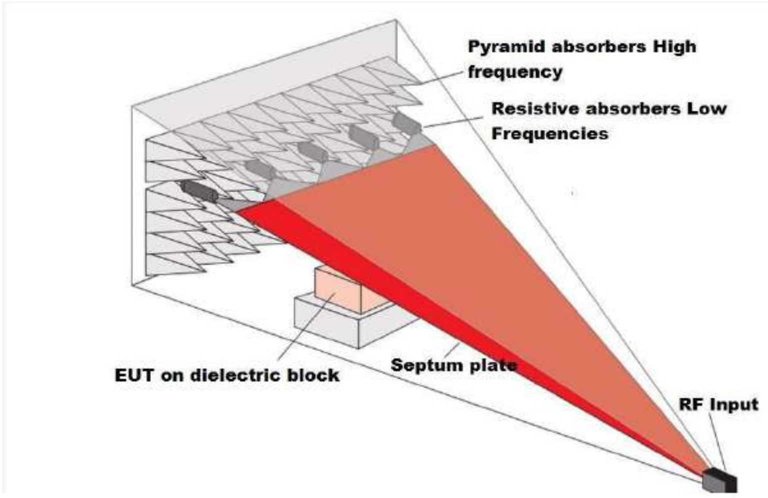


Figure 4.11: Radiated Susceptibility Test in GTEM Cell

4.5.2 Electrostatic Discharge (ESD) Test

ESD testing is a very common form of EMC immunity testing. Electric current finds the shortest and easiest path to flow. This flow will last when there is a potential difference between two points. Difference in the amount of electric charge causes a potential difference. Depending on the material, anything would pick up electric charge, but at different magnitudes. When two objects come close by, the difference in potential begins to find a path to equalize the charges. Sometimes the difference is so high that it tries to jump across the small gap between our hand and the metal handle. That's ESD in action - our body (or the EUT's Body) accumulates a large voltage(Charge) and when we touch the EUT, this voltage differential (of several kV) causes a spark to arc between our body and the EUT.

ESD testing involves applying electrostatic discharges to any areas of your product that are normally accessible to a human touch. The system-level ESD-immunity test simulates the ESD of a human onto an electronic component. Electrostatic charge on a human can develop in low relative humidity, on low-conductivity carpets, and on vinyl garments. To simulate a discharge event, an ESD generator applies ESD pulses to the EUT (equipment under test) in two ways. The first is through contact discharge, or direct contact with the EUT, in which something makes physical contact with the EUT. The second is through air-gap discharge, or indirect contact with the EUT, in which the discharge occurs through the air.

There are two types of discharge tips used for ESD testing namely Air discharge tip and Contact discharge tip.

The air discharge tip is used for Air Discharge ESD test. During an 'air discharge' test, the tip is charged up to full voltage, then the tip is moved closer to the EUT. When the tips gets close to a conductive surface with a sufficiently large potential difference (usually ground), a spark will arc across to the device.

The contact discharge tip is used for Contact Discharge ESD test. During an 'contact discharge' test, the uncharged tip makes contact with a point on the EUT. The test engineer then engages the trigger on the ESD simulator which charges the tip up to the test voltage and discharges the energy through the EUT (if a discharge path exists). An electrostatic discharge to our product

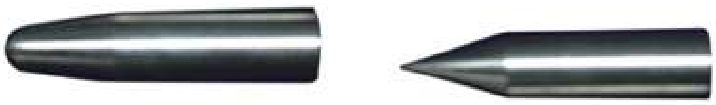
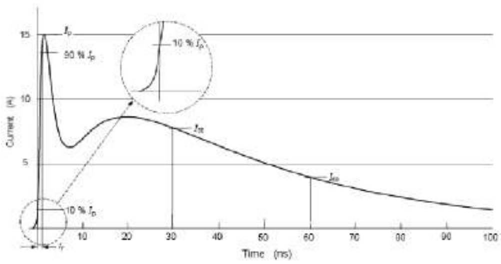


Figure 4.12: An Air and Contact Discharge Tips for ESD Gun



ESD Test Levels			
Contact discharge		Air discharge	
Level	Test voltage kV	Level	Test voltage kV
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
x[a]	Special	x[a]	Special
a) "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification. If higher voltages than those shown are specified, special test equipment may be needed.			

Figure 4.13: ESD Waveform and different ESD Test Levels

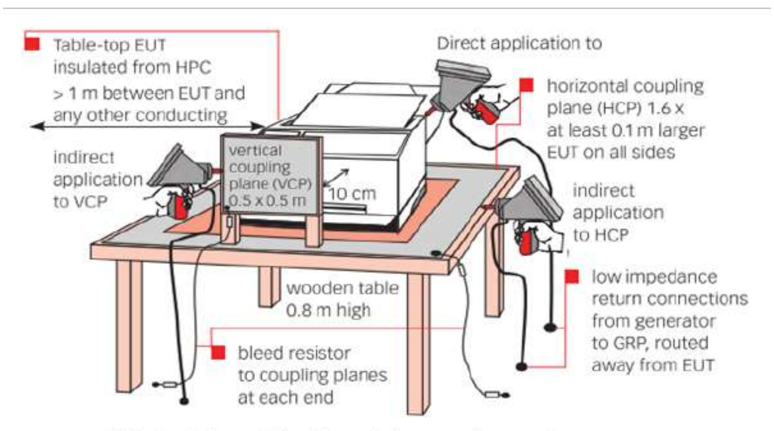


Figure 4.14: ESD Setup for Table Top Equipments

happens really quickly. As can be seen from the diagram, the bulk of the energy has dissipated within 100ns. Characteristics for this test are a rise time of less than 10 nsec and a pulse width of approximately 100 ns, indicating a low-energy, static pulse. That means that any protection circuitry you select has to be able to react quickly to ESD events. A very common test level is 4kV contact, 8kV air, but these values could be higher or lower depending on the standard.

4.5.3 Electric Fast Transient(EFT) Test

The EFT or burst immunity test simulates transients that can happen in everyday environments due to switching off inductive loads, relay-contact bounce, and the operation of dc or universal motors. This test is performed on all power, signal, and earth wires. A burst is the sequence of pulses with a finite duration.

Few examples of inductive load switching that could perceivably affect the product are toggling electric switch nearby, bundled cables can capacitively couple disturbances from switched loads on other cables, motors and relays and fluorescent lamp ballasts etc.

EFT is a transient EMC immunity test, so the disturbances happen very quickly. In the EFT-immunity test, a burst generator produces a sequence of test pulses that attenuate to 50% of their peak values in less than 100 nsec. The next adjacent pulse typically occurs 1 sec later. A burst typically lasts for 15 msec, and the burst period, the time from one bursts start to the next bursts start, is 300 msec.

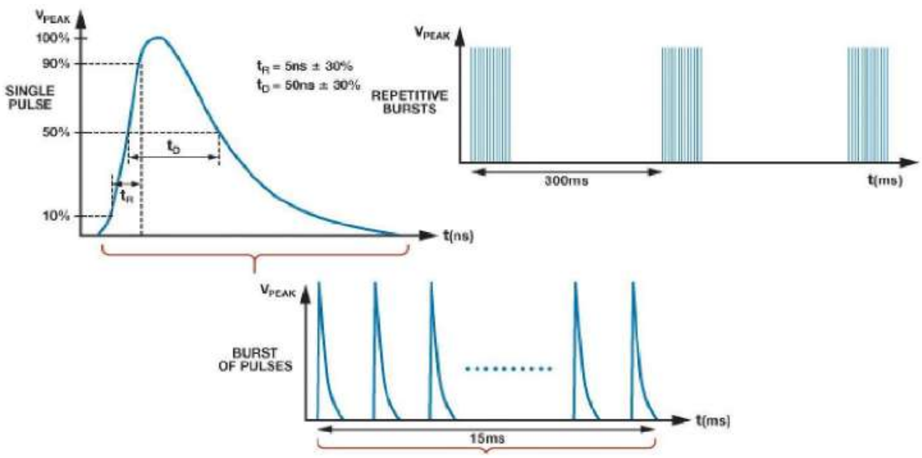


Figure 4.15: EFT Pulse Waveform

The test involves several 'bursts' of these pulses, with a delay inbetween bursts. The length of the bursts, the frequency of the pulses and the delay between bursts varies between standards.

There are a couple of injection points and methods for EFT. The first and most common is via an AC power cable. Even if you're using an external AC-DC power adapter, an EMC lab will most likely still inject EFT pulses onto the line and neutral wires. Also, EFT is normally applied capacitively to signal/control ports who's cables will be $> 3m$ in length. For capacitive coupling, the signals are simply fed through a capacitive coupling clamp, which couples the disturbance to the cables.

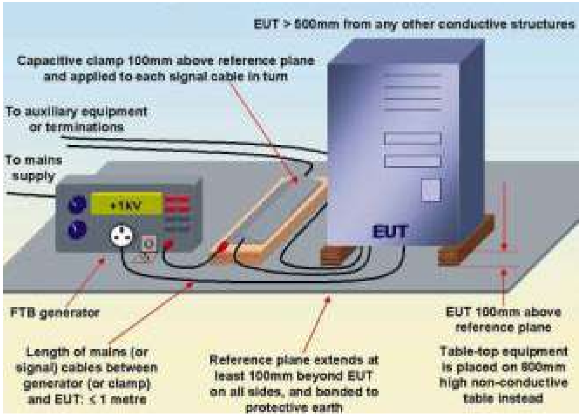


Figure 4.16: EFT test setup

Some of the common issues that can happen to the EUT due to EFT are EUT resets, damage to ICs/hardware, failing auxiliary equipment, communications links drop out, temporary analog measurement errors, audible clicking (audio products), etc.

4.5.4 Surge Test

The surge-immunity, or lightning test represents the most severe transient-immunity test in current and duration. The surge immunity test is designed to simulate low frequency power surges. However, testers often employ it on signal and power lines longer than 30m. The surge-immunity test simulates switching transients due to direct lightning strikes; induced voltages and currents due to indirect strikes; or switching the power systems, including load changes and short circuits.

Few examples of places where we should expect to see surge events are power switching events, insulations faults on the power grid, nearby switching reactive loads (e.g. motors), fuses blowing (flyback voltage), nearby (indirect) lightning strikes. A typical product plugged into a residential AC power socket can expect to see 3 x 6kV power surges per year!

The test specifies the surge generators output waveforms for open- and short-circuit conditions. The ratio of the open circuits peak voltage to the short circuits peak current is the generators output impedance. High current due to low generator impedance and pulse duration approximately 1000 times longer than the ESD- and EFT-immunity tests characterize this test, indicating a high-energy pulse.

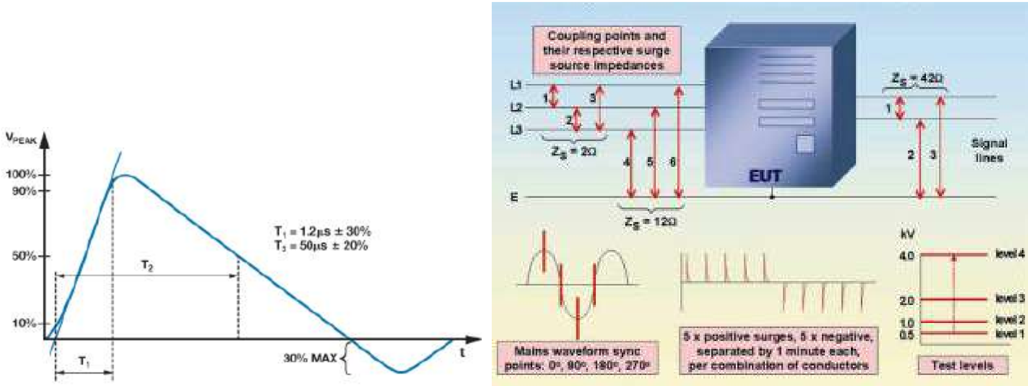


Figure 4.17: Surge Pulse and Coupling methods

Surge is usually applied to AC (or DC) power input ports, but in some standards, it is also to be applied to signal ports. The surge pulses are usually coupled directly to the signals via a carefully defined source impedance (e.g. 2, 18uF in series). The coupling network is usually contained inside an immunity test system along with a decoupling network which helps to protect the power supply or auxiliary equipment.

Surge testing involves a lot of energy. The currents involved can easily exceed 100A for a short period of time. With this amount of energy, it's really easy to do damage to the EUT. Some of the common issues that can happen are frying ICs, cabling breakdown, thermal issues, arcing, damage to motor windings, etc.

4.5.5 POWER FREQUENCY MAGNETIC FIELD TEST

The magnetic fields to which equipment is subjected may influence the reliable operation of equipment and systems. There are a few types of components that can be particularly susceptible to magnetic field like relays, CRT monitors, Hall elements, Electrodynamic microphones, Magnetic field sensors etc.

These tests are intended to demonstrate the immunity of equipment when subjected to power frequency magnetic fields related to the specific locations and installation condition of the equipment (e.g. proximity of equipment to the disturbance source like distribution transformer, mains power lines carying high currents etc). The power frequency magnetic field is generated by power frequency current in conductors or, more seldom, from other devices (e.g. leakage of transformers) in the proximity of equipment.

The EUT is subjected to a continuous magnetic field of 3 A/m or 10 A/m and 100 A/m, 1000 A/m for short duration by use of an induction coil of standard dimensions 1m x 1m. The induction coil is then rotated by 90^0 in order to expose the EUT to the test field with different orientations. Three orthogonal planes are tested. The dwell time at each frequency is not less than the time necessary for the EUT to be exercised, and able to respond.

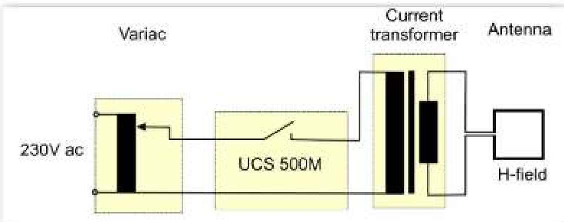


Figure 4.18: Generation of Magnetic Field

The magnetic field strength is expressed in A/m; 1 A/m corresponds to a free space induction of 1.26 T. For power line magnetic field testing, the setup is pretty simple. As can be seen in fig 4.18 that a variac is connected to the mains AC voltage. The tap point of the variac define the voltage that's fed to a current transformer. By varying the voltage, we can vary the current in the H-field antenna (the transducer) and therefore set the magnetic field strength (measured in Amps/m). The antenna is just a loop or several loops of electrical wire. The varying current through these loops generates a magnetic field. The EUT sits within the antenna so that it's subjected to a uniform magnetic field.

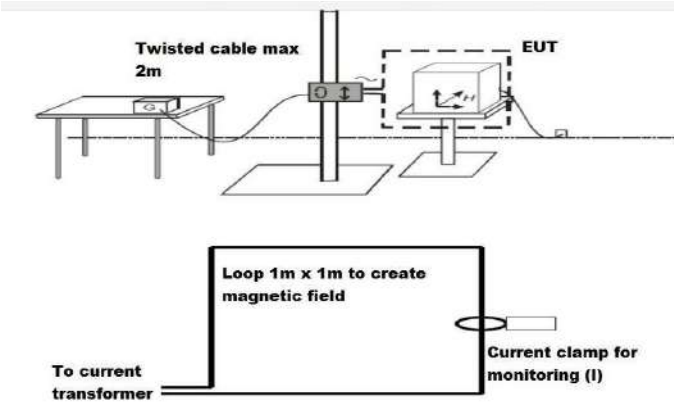


Figure 4.19: Power Frequency Magnetic Field Test Setup

4.5.6 Damped Oscillatory Test

Repetitive damped oscillatory waves are phenomena associated with the opening and closing of high voltage (HV) busbars in high voltage (HV) and medium voltage (MV) power transmission stations. The physical environment influences the fundamental oscillation frequency and repetition of the impulses.

The most common type of switch used in power distribution is an air insulated type which has been measured as generating damped oscillatory impulses up to 1MHz with a repetition rate up to 400Hz. Damped oscillatory impulses up to 1MHz are termed "Slow Waves".

- Damped Oscillatory Fast Waves (3MHz, 10MHz and 30MHz) : "Fast" repetitive damped oscillatory waves occur mainly in power, control and signal cables installed in gas insulated (GIS) high voltage and medium voltage (HV/MV) substations The event has a relatively high transfer impedance resulting in a voltage impulse. A normalised voltage impulse of a damped sinewave as defined in the standard IEC 61000-4-18 has become an industry standard. Typical impulse amplitudes are up to 4000 volts.

- Damped Oscillatory Slow Waves (100kHz and 1MHz) : Slow repetitive damped oscillatory waves occur mainly in power, control and signal cables installed in air insulated (AIS) high voltage and medium voltage (HV/MV) substations. The event has a relatively high transfer impedance resulting in a voltage impulse. A normalised voltage impulse of a damped sinewave as defined in the standards IEC 61000-4-18 and ANSI C37.90 are an industry standard. Typical impulse amplitudes are up to 3000 volts.

- Damped Oscillatory Magnetic Fields (100kHz and 1MHz) : The damped oscillatory magnetic fields are generated by busbars located in medium voltage and high voltage sub-stations. IEC61000-4-10 specifies the test method for electronic equipment. A 1m x 1m antenna is used to generate the magnetic (H) fields.

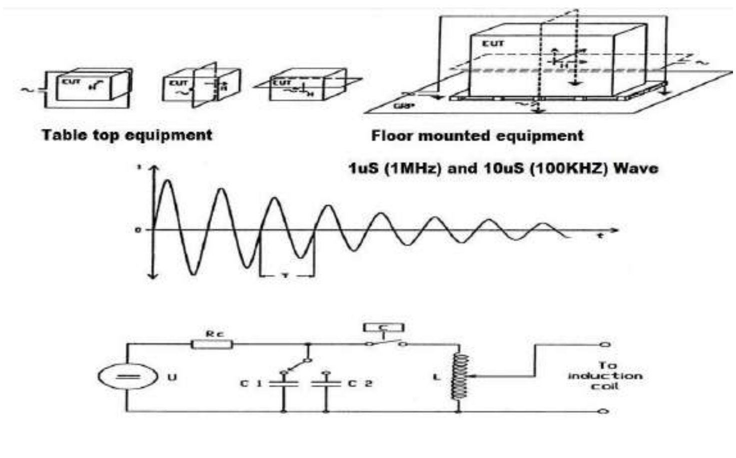


Figure 4.20: Damped Oscillatory Magnetic Field Test

4.5.7 VOLTAGE DIPS AND INTERRUPTION TEST

Voltage dips and short interruptions are caused by faults in the network, in installations or by a sudden large change of load. In certain cases, two or more consecutive dips or interruptions may occur. Voltage variations are caused by the continuously varying loads connected to the network.

These phenomena are random in nature and can be characterized in terms of the deviation from the rated voltage and duration. Voltage dips and short interruptions are not always abrupt, because of the reaction time of rotating machines and protection elements connected to the power supply network. If large mains networks are disconnected (local within a plant or wide area within a region) the voltage will only decrease gradually due to the many rotating machines, which are connected to the mains networks. For a short period, the rotating machines will operate as generators sending power into the network. Some equipment is more sensitive to gradual variations in voltage than to abrupt change. Most data-processing equipment has built-in power-fail detectors in order to protect and save the data in internal memory so that after the mains voltage has been restored, the equipment will start up in the correct way. Some power-fail detectors will not react sufficiently fast on a gradual decrease of the mains voltage. Therefore, the d.c. voltage to the power-fail detector is activated and data will be lost or distorted. When the mains voltage is restored, the data-processing equipment will not be able to restart correctly before it has been re-programmed.

This EMC test is to simulate voltage dips and short brownouts on AC or DC power supplies. It helps to ensure that your equipment functions properly (as expected and safely) with power supply fluctuations. The duration of the voltage dip and the depth of the dip vary and are defined in the standard.

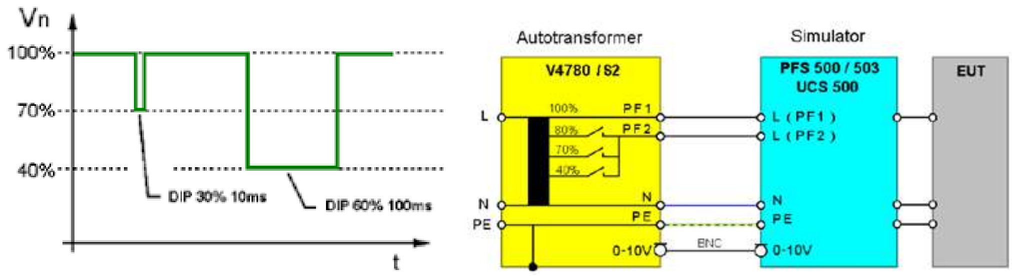


Figure 4.21: Voltage dip depth & duration and Simulator schematics

A tapped auto-transformer selects the dip level and an immunity test system controls the selection using an analog feed signal. The immunity test system controls the length of the dip and switches between 100% and the dip signal to create the momentary drop in voltage.

Class[a]	Test level and durations for voltage dips (t_s) (50 Hz/60 Hz)				
Class 1	Case-by-case according to the equipment requirements				
Class 2	0 % during ½ cycle	0 % during 1 cycle	70 % during 25/30[c] cycles		
Class 3	0 % during ½ cycle	0 % during 1 cycle	40 % during 10/12[c] cycles	70 % during 25/30[c] cycles	80 % during 250/300[c] cycles
Class X[b]	x	x	x	x	x

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels must not be less severe than Class 2.

[c] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

Figure 4.22: Preferred test levels and durations for voltage dips

4.6 Pass Criteria for EMC immunuity test

To evaluate whether the EUT passes or fails each EMC immunity test, an EMC test lab needs to know what an acceptable degradation of performance actually is. We need to monitor the equipment during and after each test and watch for any changes to the behavior or operation.

The performance of the EUT usually falls into categories A,B,C and D, but this is dependent on the standard that applies to the EUT. The four categoriesare described as:

- **Class A** : The device lying in this class is considered perfect. That means the device performs normally and within specifications specified, usually in the product manual, during and after the test. So essentially nothing bad happeness to the device during or after the test.
- **Class B** : The device lying in this class may have had a temporary loss of function or degradation of performance during the test which ceases after the applied disturbance ceases. So after the test finishes, the equipment under test recovers its normal performance without operator intervention. That just means that the operator didn't have to do anything to get it back into a mode that it was in before the test started.
- **Class C** : This class is same as class B, but operator intervention is allowed as well. So maybe the operator has to power the device back on. Maybe the EMC phenomena reset the device and operator may need to power it back on manually.
- **Class D** : Class D is that there's a loss of function or degradation of performance which is not recoverable, owing to damage to hardware of software or loss of data. So basically in some way the test has trashed the product. It might have fried some components or caused corruption of some data. If a device comes under this criteria then it is stated as Non-Compliant i.e. it has failed the EMC immunity test.

Chapter 5

EMC Standards

In the past, most countries had their own regulations and standards governing Electromagnetic Interference (EMI) or Radio Frequency Interference (RFI). Then on January 1, 1992, the European Directive 89/336 EEC on Electromagnetic Compatibility (EMC) came in to force. This directive brings a common approach to EMC to every member state of European Union. Common standards will be used throughout Europe to ensure that technical trade barriers are removed. As well as controlling EMI emission from equipment, the directive also calls for equipment to be immune to external electromagnetic disturbances. The task of elaborating the standards to be used has been assigned the European Organization called CENELEC. The most of European standards will be based upon International Standards from IEC and CISPR. The numbering system used in European Standards is:

$$EN_{xxyyy}:$$

EN= European Norm. 'xx'= 50 denotes that the standard is a standard of CENELEC origin. 'yyy' is just a continuous number. If 'xx'= 55, the standard is based on CISPR Standard 'yyy'. CISPR 13 therefore becomes EN 55013. Standards based on an IEC Standard 'yyy' are indicated with 'xx'= 60. The numbering of these standards is harmonized between IEC and CENELEC, and as a result these standards are often described like IEC/EN 61800-3, which would be the EMC product family standard for power drive systems.

5.1 Standards Classification

The standards in the international system are divided in to three different categories:

5.1.1 Basic Standards

Basic standard describes the general and fundamental rules for meeting the requirements. Terminology, phenomena, compatibility levels, measurement, test techniques and classification of EM environments are so described with in. The EN 61000-4-x is series of standards are the best known examples for basic standards.

5.1.2 Generic Standards

Generic standards refer to specific environments. They set minimal EMI levels that equipment in these environments must meet. Where no specific product standards exist, the generic standards are to be used. Generic standards describe household and industrial EMI environments. Examples of Generic Standards are EN 61000-6-1/2/3/4. Product standards are for specific product or product groups. These standards are coordinated with the Generic standards.

5.1.3 Product Standards

Product Standards always take precedence over Generic Standards. If a product or product family standard exists for a certain product, the manufacturer must use this standard. Only in the absence of a product standard can a manufacturer use Generic Standard.

5.2 Common Limit Lines

There are various standards set down limits for Conducted and Radiated EMI emission. These limits are defined in dBV for conducted voltage and dBV/m for radiated field strength. The reference values are $1V$ for $0dBV$ and $1V/m$ for $0dBV/m$. Typically limit lines are defined separately for residential areas and industrial areas. These two areas are represented by two classes of limits:

- Class A represents the industrial environment.
- Class B represents the residential areas.

While a number of different limit lines exist for various standards, the Class A and Class B limits of EN 55011 and EN 55022 have become the reference limit for most of standards.

5.3 Safety Approvals

5.3.1 CE Mark

The letters “CE” are the abbreviation of French phrase “Conformit Europene” which literally means “European Conformity”. The term initially used was

"EC Mark" and it was officially replaced by "CE Marking" in the Directive 93/68/EEC in 1993. "CE Marking" is now used in all EU official documents.

CE marking is a mandatory conformity marking for certain products sold within the European Economic Area (EEA) since 1985. The CE marking is also found on products sold outside the EEA that are manufactured in, or designed to be sold in, the EEA. This makes the CE marking recognizable worldwide even to people who are not familiar with the European Economic Area. It is in that sense similar to the FCC Declaration of Conformity used on certain electronic devices sold in the United States.

5.3.2 UL Mark

The "UL" mark stands for "listed" and identifies units whose use for the generally accepted applications in the relevant field is not restricted. Here we feature the UL mark on the medical and safety facility filters and power quality products.

5.3.3 RU Mark

The mirror image "RU" stands for "recognized" and identifies tested products or components that are subsequently used in UL- certified end products, machine or system. A good share of our standard and customized components such as chokes and filters bear this level.

5.3.4 Recognised Component Mark for Canada and U.S

This UL recognized component mark, which became effective in April 1998, may be used on components certified by UL to both Canadian and U.S requirements. Although UL had not originally planned to introduce a combined Recognized Component Mark, the popularity of the Canada/U.S listing and classification marks among clients with UL certification for both Canada and United States led to this mark.

5.3.5 ENEC Mark

The ENEC Mark for lightning components, IT components, Transformers, Equipment Switches, Control Units, Clamping Devices and connector plugs, Capacitors and RFI suppression components documents the uniform Europe-wide Certification in the ENEC procedure according to EN Standards.

5.3.6 CSA Mark

A CSA Mark on its own, without indicators, means that the product is certified primarily for the Canadian market for the applicable Canadian Standards. If a product has features for more than one area (such as electrical equipment with fuel-burning feature), the mark indicates compliance with all applicable standards.

5.3.7 China Quality Certification Standard Mark

CQC develops voluntary product certification services called CQC Mark Certification for products not subject to compulsory certification. The objective is to protect consumers, ensures the safety of persons and property, safeguards the rights and interests of users, improves the product quality and international competitiveness of Chinese enterprises.

Conclusion

In this growing market and advancement in science and technology, thousands of various devices and equipments are being designed and manufactured on a daily basis. Every electrical and electronic product generates electromagnetic energy thereby making it so imperative for this electromagnetic energy to interfere within (or outside) the system of these devices. This electromagnetic energy should not alter the performance of the device in any undesired way failure to which the device can be rendered malfunctioning. Hence, every device should be electromagnetically compatible with itself and with its surroundings.

On the other hand, in todays competitive world in electronics manufacturing field the EMI/EMC testing has a very much importance. For a high quality market value for an electronic system, it is necessary that the system must be EMI/EMC compliant. To comply with the EMI/EMC standards, the manufacturers must design their products keeping in mind that their end product has to come for the testing and must comply.

NO DUE CERTIFICATE

This is to certify that **Mr. Swatantra Kumar Singh**, Reg. No. **IMEITY/2018/00308** under Digital India Internship Scheme of Ministry of Electronics and Information Technology, from 11th June to 10th Aug 2018 has undergone training in this organization, STQC Directorate, Electronics Regional Test Laboratory (North),New Delhi.

Nothing is due on him.

Rajni
20/8/18

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