BASIC EMC PHENOMENA AND WORLDWIDE EMC REGULATION

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Abstract: This article provides an overview of EMC standards and their use for verifying compliance with worldwide regulations. The article shows some fundamental concepts of electromagnetic compatibility. Describes the regulation in Europe , USA, and other markets, use of standards, basic EMC phenomena, EMC sources and victims and EMC test procedures.

Osnovni EMC pojavi in zakonodaja na področju EMC

Kjučne besede: elektromagnetna kompatibilnost, EMC, izvori EMI, EMC zakonodaja, EMC ustreznost

Izvleček: V prispevku podajamo pregled EMC standardov in njihovo uporabo pri preverjanju ustreznosti glede na svetovno zakonodajo. Podajamo tudi nekaj osnovnih konceptov elektromagnetne kompatibilnosti. Opišemo zakonodajo v Evropi, ZDA in na drugih trgih ter opišemo uporabo standardov, osnovne EMC pojave, izvore in žrtve EMC motenj ter EMC testne procedure.

1. Introduction

Many electronic engineers heard first time for EMC, when the product they designed has serious problems of electromagnetic compatibility. The Electromagnetic compatibility (EMC) became one of the most important technical characteristics of new electronic devices for free access on global markets. The article describes:

- Worldwide regulation like U.S. FCC requirements and European EC Directives, VCCI approval in Japan.
- Harmonised and voluntary Standards
- Basic standards
- EMC phenomena: low frequency emission (harmonic, flicker), radio-frequency emission, immunity: ESD, fast transients, surge, RF fields.

This article provides an overview of EMC standards and their use for verifying compliance with regulations.

2. Worldwide regulation and EMC phenomena

EMC is defined as the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to anything in that environment. EMC requirements concern two basic concepts: emissions and immunity or susceptibility. Electromagnetic disturbance is any phenomenon that may degrade the performance of a device, equipment, or system, or adversely affect living or inert matter. Electromagnetic interference (EMI) is the degradation of the performance of a device, transmission channel, or system caused by an electromagnetic disturbance. Disturbances may represent low-frequency (LF) and/or high-frequency (HF) phenomena, as well as broadband and/or narrowband. Broadband disturbances can originate from commutator motors, ignition systems, arc welding equipment, etc.; narrowband from digital electronic circuitry, switched-mode power supplies, and radio communication equipment. Computers have often been reported to cause interference with radio services, including police, aeronautical and broadcast services. On the other hand, radio transmission by a high-frequency carrier, such as a 900 MHz cellular or a 1.8 GHz DCS, can cause problems in computers and all electrical circuits because the carriers are easily picked up by cables and apertures functioning as antennas and are demodulated in electronic circuits by different nonlinear electromagnetic phenomena.

In industry, it is assumed that electronic control systems can be used in conjunction with interfering switching operations, motor drives, high-frequency ovens, welding equipment, etc. In a car, electronic automatic systems must function when we use our mobile phone or meet other vehicles (with interfering ignition systems). An electronically controlled wheelchair is presumed to function normally even when the person sitting in the chair uses a mobile phone or a portable PC. We demand that life-supporting

electromedical apparatus in a hospital function safely even near high-frequency-radiating surgical equipment.

2.1 Worldwide regulation on EMC

The regulation can be mandatory like in USA, Russia, Europe, Australia, and China or voluntary, like in Japan.

Let's see differences in the regulation approach in some bigger markets.

2.1.1 US Requirements

Only radio-frequency disturbances are regulated in the USA for most of devices. The general EMC requirements in the U.S. are set by the Federal Communications Commission (FCC). Mandatory FCC requirements primarily concern computing devices, defined as any electronic device or system that generates and uses timing pulses at a rate in excess of 9kHz and uses digital techniques. FCC Part 15 covers radio frequency devices capable of emitting RF energy in the range of 9 kHz–200 GHz. Testing should be done according to ANSI C63.4-1992.

Part 18 covers industrial, scientific, and medical (ISM) equipment, defined as any device that uses radio waves for industrial, scientific, or medical purposes and is not intended for radio communications. While most FCC regulations only concern emissions, FDA also requires immunity for certain life-support equipment. FCC Parts 15 and 18 include regulations as well as technical aspects and limits. FCC Part 68, which governs the technical requirements for registration of telecom terminal equipment, includes lightning surge tests (surge immunity).

FCC Part 15 currently has three different procedures for showing conformance:

Procedure of verification: where the manufacturer or the importer files a test report showing compliance. Procedure of verification is applicable for many digital devices and power supplies, which are not dedicated to be used in PC.

Procedure of certification: which requires a review of the application by the FCC, and the use of a unique FCC identification number. Procedure of certification is used e.g. for CB receivers or scan receivers.

Procedure of declaration of Conformity (DoC), which requires that tests are performed by a test lab accredited by A2LA or NVLAP (other accredited labs may also be accepted). Doc procedure is used e.g. for personal computers and peripherals.

2.1.2 EU Requirements

The European EMC Directive, 89/336/EEC, sets out the legal requirements on EMC for principally all electric/electronic equipment to be placed or used in the Common Market of European Economic Area. The European legislation covers emissions as well as immunity.

The EMC requirements are valid for apparatus and systems placed on the market as complete units. Components such as resistors or transistors are not included. However, components with a direct function to the end-user, like plug-in PC boards, are regarded as equivalent to apparatus and have to follow the same rules as other devices.

New Approach European Directives only set out essential requirements and legal aspects. Technical aspects are dealt with in specific standards. These standards are developed by specific bodies, such as CENELEC or ETSI, and are harmonized to the directives by the action of the European Commission. The harmonised standards are published in official journal of EU and public available: http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist/emc.html

The EMC Directive itself, however, is based on a presumption principle, which means that a product that meets the requirements of the harmonized standards is also presumed to meet the essential requirements of the EMC Directive.

2.1.3 EMC requirements in Russia federation

Free access to the Russian market is allowed only for products certified by GOST R accredited certification bodies. The requirements for GOST R certification are: safety, EMC and hygienically requirements for some products. The certification is based on test reports from accredited test laboratories. Most of GOST R standards are same as IEC standards. Russian legislation covers emissions and immunity. Technical requirements are same as European for many products.

2.1.4. Australian and NZ requirements

To comply with the EMC regulatory arrangements, Australian and New Zealand suppliers must satisfy four basic requirements:

Ensure that the product complies with the appropriate mandated EMC standard, make and hold a DoC, prepare and keep compliance records, label the product with the C-Tick mark.

European harmonised standards, international IEC CISPR standards or AS/NZ standards are mandatory.

A company or person wishing to use the C-Tick mark must make a written application to the ACA (Australian Communication Authority).

2.2 Standardization

Under the General Agreement on Tariffs and Trade (GATT) and its successor, the World Trade Organization (WTO), member countries are obliged to adopt international standards for national use wherever possible. International standards concerning EMC are primarily developed by the International Electrotechnical Commission (IEC: TC77 and CISPR).

The International Organization has also published some specific EMC standards for Standardization (ISO). North American EMC standards are published by the FCC, the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers (IEEE). EMC are developed by the European Committee for Electrotechnical Standardization (CENELEC).

Regulations and standards concerning telecom and radio transmitting equipment are published by the International Telecommunications Union (ITU) and the European Telecommunications Standards Institute (ETSI).

International and European EMC standards are to a great extent becoming harmonized, due to the fact that many EN standards are based on IEC and/or CISPR standards. Russian standards are published by GOST R .

EMC standards are continuously being developed and revised. It is therefore important to keep track of standards' publication dates, in addition to knowing if a new standard is to be expected in the near future and when an old standard is no longer valid.

Standard Requirements

Standards are principally divided into the following main groups: Generic, basic and product (product family) standard

Basic Standards

Basic standards describe EMC phenomena and test methods. One of series of basic standards for immunity are IEC 61000-4-X, which were then translated into European standards as EN 61000-4-X.

Product and Product Family Standards

These are applicable for specific product types, which are specified within the scope of the standard.

In addition to these standard documents, there are also standards offering guidance on installation techniques, or a code of practice, for example the IEC 61000 series, Part 5 (IEC 61000-5-X).

EMC Standards Classification

Generic standards have two environmental classes:

1. Residential, commercial, and light industrial environments, including domestic, office, laboratory, and light industrial environments where the apparatus or system is connected to the public mains.
2. Industrial environments, meaning "heavy" industrial environments with separate transformer stations for mains supply, usually with equipment spread over some distance.

Which Standards Apply?

A product standard is one that covers many EMC requirements for a certain product type. In some cases, product standards also cover electrical safety requirements. A product standard takes preference over all other standards. If some EMC phenomena is not covered by product standards , generic standard should be used for that phenomena. (e.g. immunity, low frequency emission) Once it is determined that a product is within the scope of an applicable product family standard concerning emissions and/or immunity, then that standard should be followed. The Guide 25 published by CENELEC can be used for proper harmonised standards decision: http://www.cenelec.org/NR/rdonlyres/0BD1127F-9C5C-4FB8-8854-17905BF7ABAC/0/CENELECGuide25.PDF

Generic/General Standards

If no product family standard is applicable, one must follow the suitable generic or general standard, which in turn refers to different basic standards. Some of the product family standards are also referred to in other standards, which consequently gives them characteristics of basic standards.

The generic standards include:

EN 61000-6-3: Emissions standard for residential, commercial, and light industrial environments.

EN 61000-6-4: Emissions standard for industrial environments.

EN 61000-6-1: Immunity standard for residential, commercial, and light industrial environments.

EN 61000-6-2: Immunity standard for industrial environments.

EMC standard that covers emissions and immunity for medical equipment is EN 60601-1-2, the collateral standard for medical equipment. In addition to this collateral standard, there are a number of product standards covering safety and EMC for specific medical equipment, like EN 60601-2-24, which covers infusion pumps and controllers.

As far as the emissions requirements are concerned, the generic standard is more rigorous in regard to light industrial environments than on heavy industry, which as a rule is already rather electro-magnetically contaminated. As far as the immunity requirements are concerned, the situation is the opposite. Interference immunity must be harder in heavy industrial environments.

What then is applicable in mixed or special environments? When using the generic standards it is recommended to begin with the most strict requirements, which means that the equipment should be classified according to the "worst" combination, such as EN 61000-6-3/EN 61000-6-2.

2.3. EMC phenomena and EMC test procedures from basic standards

Basic Immunity Standards describes the EMC phenomena and test procedures. From historical reasons there are not particular basic standards for emission phenomena.

The procedures in some product family standards are deemed to be equivalent for basic standards.

2.3.1 Low frequency emissions - harmonics and flicker

Many electrical devices could change the quality of electrical energy by non-linear current response and fast changes of power consumption. The limits for all equipment with rated current under 16 A are regulating by standards EN 61000-3-2. Measuring of low frequency emission requires non electro-magnetically polluted sources. Harmonics are measured with harmonic analysers. Frequency range of interest starts at 50 Hz and stops at 2 kHZ.

2.3.2 Radio frequency emissions – conducted and radiated method

Many electrical and electronic devices are sources of radio-frequency disturbances. (Spark-ignition motors, commutation motors, all digital devices and so on). Radio disturbances have many propagation paths: conductive, capacitive, inductive and radiated. Conductive path is predominant at lower frequencies (150kHz to 30MHz) and radiated path is predominant at higher frequencies (above 30MHZ).

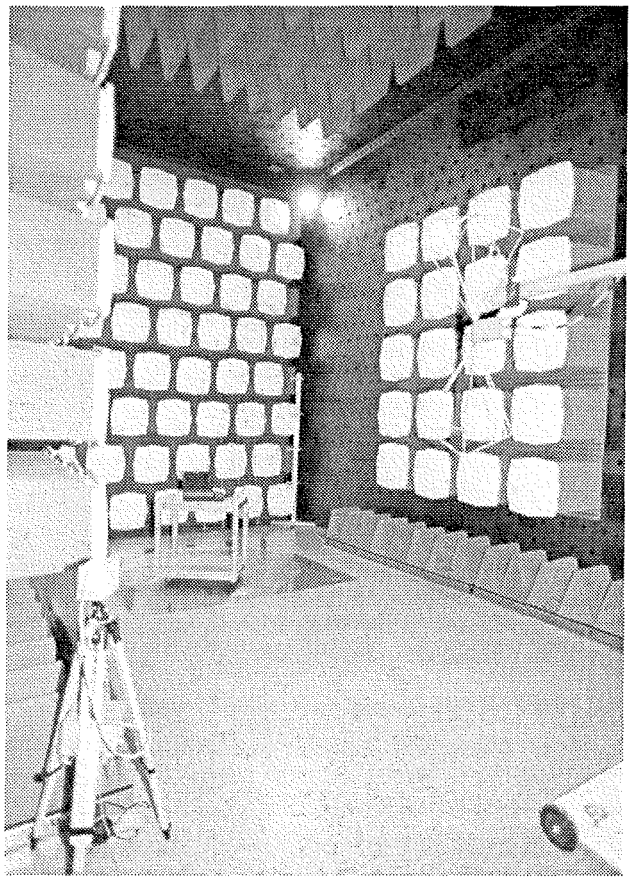

Figure 1: Anechoic chamber in Slovenian institute of Quality and Metrology. Testing according to EN 55022 on 3m distances and immunity according to EN 61000-4-3 up to 3GHz.

2.3.3 Immunity to electrostatic discharges (ESD)

This test relates to equipment, systems, sub-systems and peripherals which may be involved in static electricity discharges owing to environmental and installations conditions, such as low relative humidity, use of low-conductivity (artificial-fiber) carpets, vinyl garments, etc., which may exist in allocations classified in standards relevant to electrical and electronic equipment.

The problem of protecting equipment against the discharge of static electricity has gained considerable importance for manufacturers and users.

The extensive use of microelectronic components has emphasized the need to define the aspects of the problem and to seek a solution in order to enhance products/ system reliability.

The problem of static electricity accumulation and subsequent discharges becomes more relevant for uncontrolled environments and the widespread application of equipment and systems in a wide range of industrial plants.

Electrostatic discharges are applied to the EUT at points and surfaces which are normally accessible to the operator. These discharges are also applied to the metal coupling planes. The voltage levels are increased gradually until the maximum severity level selected is reached. Discharges to the EUT and coupling plane are performed at a minimum of 1 second intervals at each polarity. The minimum of 10 discharges at each polarity are initially performed and increased to 30 discharges as the voltages increase in severity so as to evaluate the performance of the EUT.

2.3.4 Immunity to Radiated, radio frequency electromagnetic fields (RF fields).

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).

The EUT is subjected to a field strength of 3 V/m or 10 V/m from 80 MHz to 1000 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.

2.3.5 Immunity to electrical fast transients/burst (EFT).

The repetitive fast transient test is a test with bursts consisting of a number of fast transients, coupled into power supply, control and signal ports of electrical and electronic equipment. Significant for the test are the short rise time, the repetition rate and the low energy of the transients.

Test voltages of up to 4 kV in positive and negative polarities are applied to the A/C power leads and up to 2 kV is applied to the I/O cables. The test voltages are at a 5 kHz pulse repetition frequency and applied for 60 seconds to each power supply terminal including protective earth and every combination of these terminals. The coupling clamp is used to apply up to 2 kV to the I/O cables.

2.3.6 Immunity to surges (1, 2 µs/50 µs).

These tests relate to the immunity requirements for equipment to unidirectional surges caused by overvoltages from switching and lightning transients. Several test levels are defined which relate to different environment and installation conditions. These requirements are developed for and are applicable to electrical and electronic equipment.

System switching transients can be separated into transients associated with:

The major mechanisms by which lightning produced surge voltages are the following:

A direct lightning stroke to an external circuit (outdoor) injecting high currents producing voltages by either flowing through earth resistance of flowing through the impedance of the external circuit;

An indirect lightning stroke (i.e. a stroke between or within clouds or to nearby objects which produces electromagnetic fields) that induces voltages/currents on the conductors outside and/or inside a building;

Lightning earth current flow resulting from nearby direct-to-earth discharges coupling into the common earth paths of the earthing system of the installation.

The rapid change of voltage and flow of current which may occur when a protector is excited may couple into internal circuits.

Test voltages of up to 4 kV are applied synchronized to the voltage phase at zero-crossing and peak value of the A.C. voltage wave (positive and negative). The surges are applied line to line and line to earth. When testing line to earth the test voltage is applied successively between each of the lines and earth. All lower levels including the selected test level is tested.

2.3.7 Immunity to conducted disturbances induced by radio frequency fields.

The source of disturbance covered by this test is basically an electromagnetic field, 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 150W with respect to a ground reference plane.

This test subjects the EUT to a source of disturbance comprising electric and magnetic fields, simulating those coming from intentional RF transmitters. These disturbing fields (E and H) are approximated by the electric and magnetic near-fields resulting from the voltages and currents caused by the test set-up.

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.

2.3.8 Immunity to magnetic fields

The magnetic fields to which equipment is subjected may influence the reliable operation of equipment and systems.

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). 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 by use of an induction coil of standard dimensions 1m x 1m. The induction coil is then rotated by 90° 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.

The preferential range of test levels, respectively for continuous and short duration application of magnetic field, applicable to distribution networks at 50 Hz and 60 Hz, is given below.

2.3.9 Immunity to voltage dips and short interruptions

Electrical and electronic equipment may be affected by voltage dips, short interruptions or voltage variations of power supply.

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.

Consequently, different types of tests are specified to simulate the effects of abrupt change voltage, and, optionally, for the reasons explained above, a type test is specified also for gradual voltage change. This test is to be used only for particular and justified cases.

The EUT is tested for test levels of 30%, 60% and >95% below the rated voltage for the equipment. The duration of the dips/interruptions are 10ms, 100ms and 5000ms respectively. Five dips are performed for each test level at a rate of one dip per minute. The changes in supply voltage occur at zero crossing of the voltage.

3. Conclusion

The article has been written as short guide for manufacturers and suppliers of devices and systems sold and installed in global markets. Market requirements for European, American, Russian and Australian market have been presented. Basic EMC phenomena and test procedures have been evaluated and described in connection with international and regional standardization. Manufacturers and suppliers can get first overview of EMC through this article. However because of complex thematic and test procedures, the further cooperation with professional organisation is strongly recommended. The professional organisations, which are most, deeply informed and competent for EMC questions are EMC competent bodies of EU and accredited laboratories that have in accreditation scope also testing for your products. Competent bodies can be found on the Internet address: http://europa.eu.int/comm/enterprise/electr_equipment/emc/cblist.htm#Slovenia

4. References

/1/ COUNCIL DIRECTIVE of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility (89/336/EEC)

/2/ Guidelines on the application of Directive 89/336/EEC: http://europa.eu.int/comm/enterprise/electr_equipment/emc/guides/chapone.htm

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