EUROPEAN UNION
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YOUTH AND SPORTS

Electromagnetic compatibility of technical systems

Study material for the subject KEI/EMC2

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Author's note

This study material is the basic literature for the subject Electromagnetic compatibility 2. It is focused in the point of view of "manufacturer of the device", it introduces to them the valid legislative and shows to them possibilities during EMC measurements, including the fundamentals of EMC. In this material, the test setups for RF EMC measurements and testing of technical systems (ie electrical / electronic devices) are shown. The low frequency EMC is not mentioned here as well as the EMC of biological systems – please do not forget these parts of EMC during the process of new device designing.

1 EMC – why do we do it?

We want to sell devices! A **declaration of conformity** is required for the European economic market. The declaration is based on the documents that prove the compliance of the device with the required legislation. In generally, three parts of documents are necessary for declaration of conformity:

- EMC compliance,
- electrical safety of equipment,
- RoHS.

If these documents exist, the manufacturer / importer of the device may issue the declaration of conformity (or it may be issued by a notified body). The device can be than marked by CE mark (see Fig. 1)

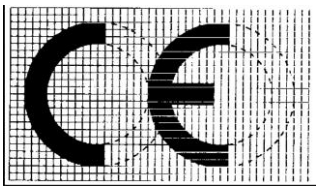


Fig. 1: CE mark

NOTE: CE vs. „China export“ and „China engineering“ marks

Fig. 1 shows only correct CE mark. There exist also imitations of it:

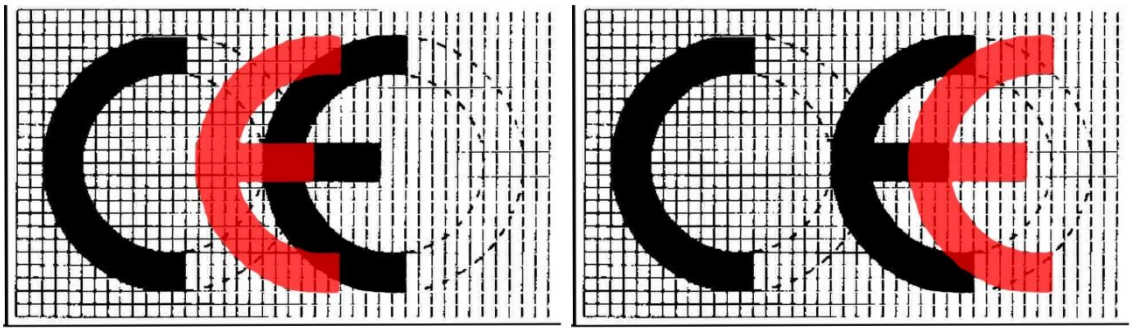


Fig. 2: Imitation of CE mark

2 Legislation and standardization in EMC

The law no. 90/2016 Sb.: *Zákon o posuzování shody stanovených výrobků při jejich dodávání na trh* z 31. 3. 2016 [1] defines an introduction of a new product on the market in the Czech Republic. The Government Regulation no. 117/2016 Sb.: *Nařízení vlády o posuzování shody výrobků z hlediska elektromagnetické kompatibility při jejich dodávání na trh* z 20. 4. 2016 [2] specifies EMC requirements for the equipment. This Regulation establishes compliance with the requirements of Directive 2014/30/EU of the European Parliament and of the Council of 26 March 2014: *Směrnice o harmonizaci právních předpisů členských států týkajících se elektromagnetické kompatibility* [3]. Directive 2014/30/EU replaced the previous Directive 2004/108 / EC [4], which was canceled on 20 April 2016. The following devices are excluded from Directive 2014/30/ EU Aacording to Chapter 1, Article 2:

- equipment covered by Directive 1999/5/EC [6],
- aeronautical products, parts and appliances as referred to in Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC,
- radio equipment used by radio amateurs within the meaning of the Radio Regulations adopted in the framework of the Constitution of the International Telecommunication Union and the Convention of the International Telecommunication, unless the equipment is made available on the market,
- equipment the inherent nature of the physical characteristics of which is such that:
    - it is incapable of generating or contributing to electromagnetic emissions which exceed a level allowing radio and telecommunication equipment and other equipment to operate as intended; and
    - it operates without unacceptable degradation in the presence of the electromagnetic disturbance normally consequent upon its intended use,
- custom built evaluation kits destined for professionals to be used solely at research and development facilities for such purposes,
- equipment subject to requirements under other Union legislation.

2.1 Standardization – legislation

Compliance with the technical standardization, which is given by law no. 22/1997 Sb.: *Zákon o technických požadavcích na výrobky a o změně a doplnění některých zákonů* z 22. 1. 1997 [11], is necessary for the fulfillment of the legislation.

Harmonized standards are inherently non-binding, but they are binding to comply with the requirements of the European harmonization regulation, in particular as regards the affixing of the CE marking to the product.

2.2 Standards for devices not subject to the Directive 2014/30/EU

There exist a lot of standards for device which shall not apply according to Directive 2014/30/EU, especially for radio and telecommunication equipment – these subject covered Directive 2014/53/EU: *Směrnice o harmonizaci právních předpisů členských států týkajících se dodávání rádiových zařízení na trh a zrušení směrnice 1999/5/ES* [14] (which replaced the original Directive 1995/5/EU). The another areas which shall not apply according to Directive 2014/30/EU are automotive, space, etc.

2.3 EU declaration of conformity, CE mark

Lot of device that are sel in EU must be marker by CE mark – it declares that the device complies with EU requirements of safety, health and environmental. Harmonized standards specify the requirements for the product placed on the market – there is necessary to prepare technical documentation that demonstrates compliance with technical requirements. For some product groups is required to verify the technical requirements by notified bodies. The conformity of the product with the legal provisions of the European Union is proved by the EU Declaration of Conformity document, which is described in Article 15 of Directive 2014/30/EU, see Annex C. If there exists the Declaration of conformity, the device is then marked with symbol CE (See Fig. 1). The format of CE mark is defined by Regilation EU no. 765/2008 [16] and it must be placed visibly, legibly and indelibly to the product. If the product has been assessed by a notified body, its identification number must also be placed to the product.

2.4 Normalization organizations and committees

Standards in EMC are usually defined and worded by international organizations and committees and harmonized by national or regional organizations and committees on behalf of administrative bodies. There exist organizations and their committees which define EMC standards:

- International:
    - IEC – International Electrotechnical Commission – Committees within IEC for Basic and Generic EMC Standards:
        - CISPR (Comite International Special des Perturbations Radioelectriques) - International special committee on radio interference,
        - TC 77 (Technical committee 77) – Electromagnetic compatibility.
    - ISO – International Standard Organization,
    - ITU – International Telecommunications Union,
- European:
    - CENELEC – Comite Europen de Normalisation en Electrotechnique,
    - CEN – Comite Europeen de Normalisation,
    - ETSI – European Telecommunications Standards Institute,
- Czech:
    - ÚNMZ – Úřad pro normalizaci, metrologii a státní zkušebnictví (before ČNI – Český normalzační institut).
    -

NOTE to standards harmonization
Today, all standards are harmonized (it could be said that they are taken over) – the harmonized ČSN standards often does not have to be fully translated into Czech – only introductory part can by translated and then the English EN standard is insterted. The EN standard can be harmonized from other organization (IEC, CISPR, ETSI), in this case can be found standard with Czech introduction part, English EN part ant whole IEC / CISPR / ETSI standard. The name is ČSN EN CISPR / ČSN ETSI EN, ETC.
! The price of the standard is equal to 1 EUR per page - extension of the standard by the Czech and European introductory parts is not negligible (for example, 10 or more pages).

2.5 EMC standards classification

One of basic criterion for EMC standard can be area if applications:

- civil standards and
- military standards.

Military standards are often different from commercial standards, especially in measurement procedures and they are also more stringent in terms of limit values, could have wider frequency ranges, higher test levels for equipment susceptibility test, etc. At present, in terms of cooperation and interconnection of the armies of the civilized world, it is possible to meet a number of standards (originally the US Armed Forces) MIL-STD. This set of standards also frequently appears in NASA and ESA space industry standards).

Division of civil (commercial) standards could be carried out according to various criteria; the liability is one important criterion. Then the standards can be divided into:

- basic standads – specify the terms and conditions for EMC testing, they define the rules necessary for achieving electromagnetic compatibility, they specify test methods and so on. Series of standards ČSN EN 55016 (emission) and ČSN EN 61000-4-X (immunity) are the most used basic standards in EMC.
- generic standards – are for products operating in a particular EMC environment (residential/industrial), where there does not exist a specific product standard. They specify a essential emission and immunity tests, as well as minimum test levels and performance criterion. The standard series ČSN EN 61000-6-X are the most used generic standards in EMC.
- product family standards / product standards – specify the limits of emission and immunity (the minimum test levels, performancecriterion) for group of products / particular product that have common general characteristics, that may operate in the same environment and have neighboring fields of application. Examples of product family standards are ČSN EN 55011, ČSN EN 55032, ČSN EN 61326, etc.

The highest priority is given to product standards (or product groups), if they do not exist, then the generic standards are applicable. These are in principle decisive for devices working in a given environment. If the environment is not specified, it is possible to perform measurements according

to the basic standards - without defined limit curves for measuring emissions or test levels in the case of resistance tests.

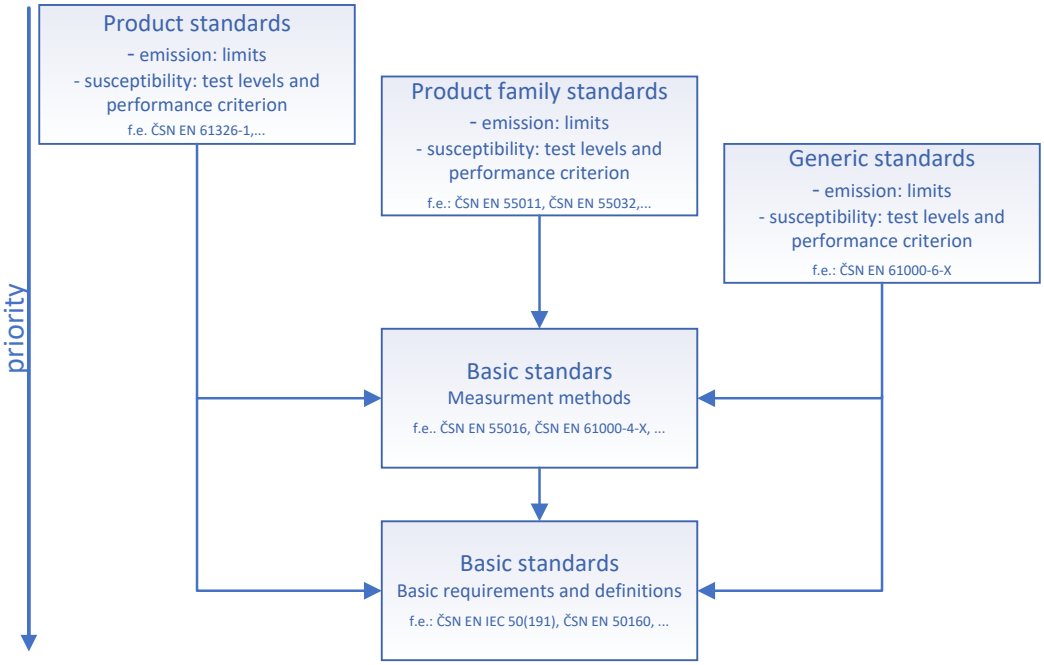


Fig. 3: Dělení EMC norem a přiřazení priority

2.6 Selected EMC standards

The basic designation of the standard is usually supplemented by an edition - the new edition can mean cosmetic changes as well as fundamental changes, which can also be added in the form of corrections and changes. Only standards without corrections (Repair <repair_number>) and changes (A <change_number> or Z <change_number>) are listed here. Documents with bold font are the most commonly used. Product standards and EMC standards for radio equipment, automotive and railway industry, etc. are not listed here in the terms of large number of them. Current as of October 4, 2021.

Generic standards – device in defined environmet	
Designation of the standard:	Document name:
ČSN EN IEC 61000-6-1 ed. 3	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments
ČSN EN IEC 61000-6-2 ed. 4	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
ČSN EN IEC 61000-6-3 ed. 3	Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for equipment in residential environments
ČSN EN IEC 61000-6-4 ed. 3	Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments
ČSN EN 61000-6-5	Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment
ČSN EN IEC 61000-6-8	Electromagnetic compatibility (EMC) –

Generic standards – device in defined environmet	
	Part 6-8: Generic standards – Emission standard for professional equipment in commercial and light-industrial locations

General test procedures	
Designation of the standard:	Document name:
ČSN EN IEC 55016-1-1 ed. 4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus
ČSN EN 55016-1-2 ed. 2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements
ČSN EN 55016-1-3 ed. 2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-3: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Disturbance power
ČSN EN IEC 55016-1-4 ed. 4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1- 4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements
ČSN EN 55016-1-5 ed. 2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration sites and reference test sites for 5 MHz to 18 GHz
ČSN EN 55016-1-6	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration
ČSN EN 55016-2-1 ed. 3	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements
ČSN EN 55016-2-2 ed. 2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-2: Methods of measurement of disturbances and immunity - Measurement of disturbance power
ČSN EN 55016-2-3 ed. 4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements
ČSN EN 55016-2-4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-4: Methods of measurement of disturbances and immunity - Immunity measurements
ČSN EN 55016-4-2 ed. 2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Measurement instrumentation uncertainty

EMS test procedures	
Designation of the standard:	Document name:
ČSN EN 61000-4-2 ed. 2	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test
ČSN EN 61000-4-3 ed. 3	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
ČSN EN 61000-4-4 ed. 3	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
ČSN EN 61000-4-5 ed. 3	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test

EMS test procedures	
ČSN EN 61000-4-6 ed. 4	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
ČSN EN 61000-4-8 ed. 2	Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test
ČSN EN 61000-4-9 ed. 2	Electromagnetic compatibility (EMC) - Part 4-9: Testing and measurement techniques - Impulse magnetic field immunity test
ČSN EN 61000-4-10 ed. 2	Electromagnetic compatibility (EMC) - Part 4-10: Testing and measurement techniques - Damped oscillatory magnetic field immunity test
ČSN EN IEC 61000-4-11 ed. 3	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase
ČSN EN 61000-4-12 ed. 3	Electromagnetic compatibility (EMC) - Part 4-12: Testing and measurement techniques - Ring wave immunity test
ČSN EN 61000-4-13	Electromagnetic compatibility (EMC) - Part 4-13: Testing and measurement techniques - Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests
ČSN EN 61000-4-14	Electromagnetic compatibility (EMC) - Part 4-14: Testing and measurement techniques - Voltage fluctuation immunity test
ČSN EN 61000-4-16 ed. 2	Electromagnetic compatibility (EMC) - Part 4-16: Testing and measurement techniques - Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz
ČSN EN 61000-4-17	Electromagnetic compatibility (EMC) - Part 4-17: Testing and measurement techniques - Ripple on d.c. input power port immunity test
ČSN EN IEC 61000-4-18 ed. 2	Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test
ČSN EN 61000-4-20 ed. 2	Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides
ČSN EN 61000-4-27	Electromagnetic compatibility (EMC) - Part 4-27: Testing and measurement techniques - Unbalance, immunity test
ČSN EN 61000-4-28	Electromagnetic compatibility (EMC) - Part 4-28: Testing and measurement techniques - Variation of power frequency, immunity test
ČSN EN 61000-4-29	Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests
ČSN EN 61000-4-31	Electromagnetic compatibility (EMC) - Part 4-31: Testing and measurement techniques - AC mains ports broadband conducted disturbance immunity test
ČSN EN 61000-4-30 ed. 3	Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement techniques - Power quality measurement methods
ČSN EN 61000-4-31	Electromagnetic compatibility (EMC) - Part 4-31: Testing and measurement techniques - AC mains ports broadband conducted disturbance immunity test
ČSN EN 61000-4-34	Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase
ČSN EN 61000-4-39	Electromagnetic Compatibility (EMC) - Part 4-39: Testing and measurement techniques - Radiated fields in close proximity - Immunity test

LF EMI	
Designation of the standard:	Document name:
ČSN EN IEC 61000-3-2 ed. 5	Electromagnetic compatibility (EMC) . Part 3-2: Limits . Limits for harmonic current emissions (equipment input current . 16 A per phase)
ČSN EN 61000-3-3 ed. 3	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ? 16 A per phase and not subject to conditional connection
ČSN EN IEC 61000-3-11 ed. 2	Electromagnetic compatibility (EMC) . Part 3-11: Limits . Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems . Equipment with rated current . 75 A and subject to conditional connection
ČSN EN 61000-3-12 ed. 2	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current 16 A and 75 A per phase
ČSN EN 50160 ed. 3	Voltage characteristics of electricity supplied by public electricity networks

RF EMI	
Designation of the standard:	Document name:
ČSN EN 55011 ed. 4	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
ČSN EN 55012 ed. 2	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers
ČSN EN 55014-1 ed. 5	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
ČSN EN 55014-2 ed. 3	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - Product family standard
ČSN EN IEC 55015 ed. 5	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
ČSN EN 55020 ed. 3	Sound and television broadcast receivers and associated equipment - Immunity characteristics - Limits and methods of measurement
ČSN EN 55024 ed. 2	Information technology equipment - Immunity characteristics - Limits and methods of measurement
ČSN EN 55025 ed. 3	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers
ČSN EN 55032 ed. 2	Electromagnetic compatibility of multimedia equipment - Emission Requirements

NOTE: Selection of the right standards for EMC certification measurements of DUT

The producer / importer of the electric / electronic device specifies the standards for EMC measurement during the offer process or it may request the testing laboratory for conformity assessment according to the specified standard.

3 Basic EMC chain

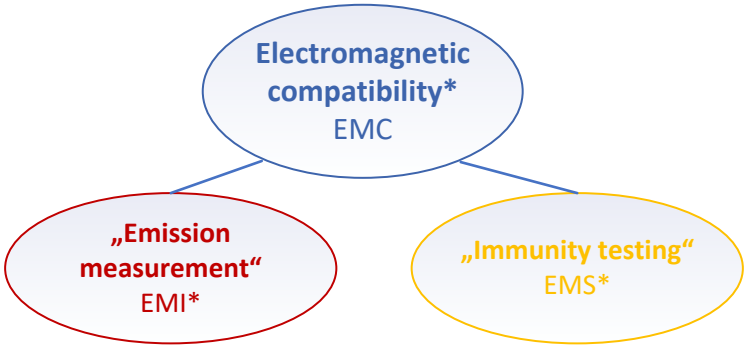


Fig. 4: Základní řetězec EMC

*Definice z ČSN IEC 50(161) - Mezinárodní elektrotechnický slovník. Kapitola 161: Elektromagnetická kompatibilita. Český normalizační institut, Praha, 1993:

electromagnetic compatibility (EMC) – ability of equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbance to anything in that environment. [ČSN IEC 50(161)/A8; 2021/09/10]

electromagnetic interference (EMI)“ – degradation in the performance oq equipment ot transmission channel or a system casued by an electromagnetic disturbance. [ČSN IEC 50(161)/A8; 2021/09/10]

(electromagnetic) susceptibility (EMS) – the inability of a device, equipment or system to perform without degradation in the presence of an electormagnetic disturbance. [ČSN IEC 50(161); 161-01-21;

4 EMC in the terms of tested device

Electromagnetic compatibility measurements are performed on enclousure of the device under test (DUT), all power supply I/O ports, all signal I/O ports or grounding connection. A block diagram of general DUT is shown in the following figure, where one type of interface is indicated; in general the device can contain a number of them (generally *n*). In some cases, it is possible to measure EMC only on one of *n* identically connected (electrically) ports, or it is not necessary to measure at all (limitation by the test procedure).

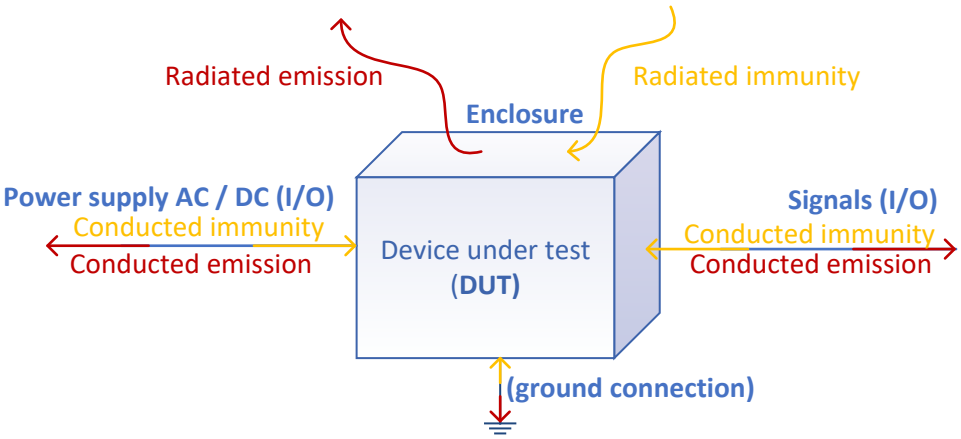


Fig. 5: Block diagram for DUT in terms of EMC

4.1 Emission measurement

The measuring setup depends on the interface that produces the electromagnetic disturbance. In generally, three basic paths of disturbing signals can be found:

- Conducted emission,
- Couplings in near field,
- Radiated emission.

There is necessary to know that each DUT interface meets the limits of the defined device standard. The Fig. 6 shows the DUT with n inputs / outputs of AC / DC power supply, n inputs / outputs of signals (signal, control, measuring interface, buses, etc.), the DUT has a hard case and it is grounded. The emission measurement is necessary for each interface (if there exists several identical interface type – electrically and functionally connected in the same way – there could be measured only one of them).

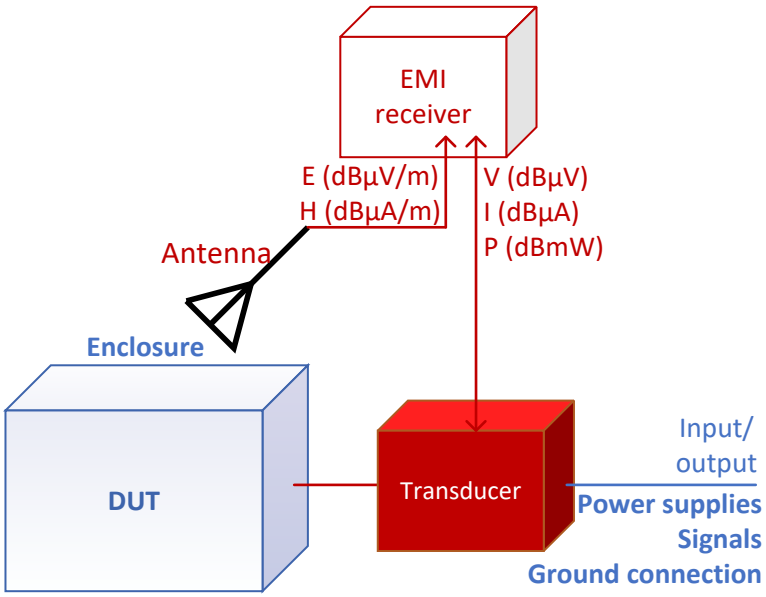


Fig. 6: Měření emisí DUT

The acreditted emission measurements can be divided into three groups according to the measurement method:

- Radiated emission are measured using antennas with defined polarization, hight and distance form DUT and with defined test-site (semi-anechoic or anechoic chamber, open site, etc.). The measurement is usually performed in the frequency ranges:
  - 9 kHz – 30 MHz; the magnetic field is usually measured using loop antennas,
  - 30 MHz – 6 GHz; the electric field is usually measured using biconical, log-periodical or double-ridged horn antennas,
  - 30 – 300 MHz; the disturbing power measuring is use like an alternative method to E-field measurement (only for standard-defined devices), for measurement is use absorption clamp.

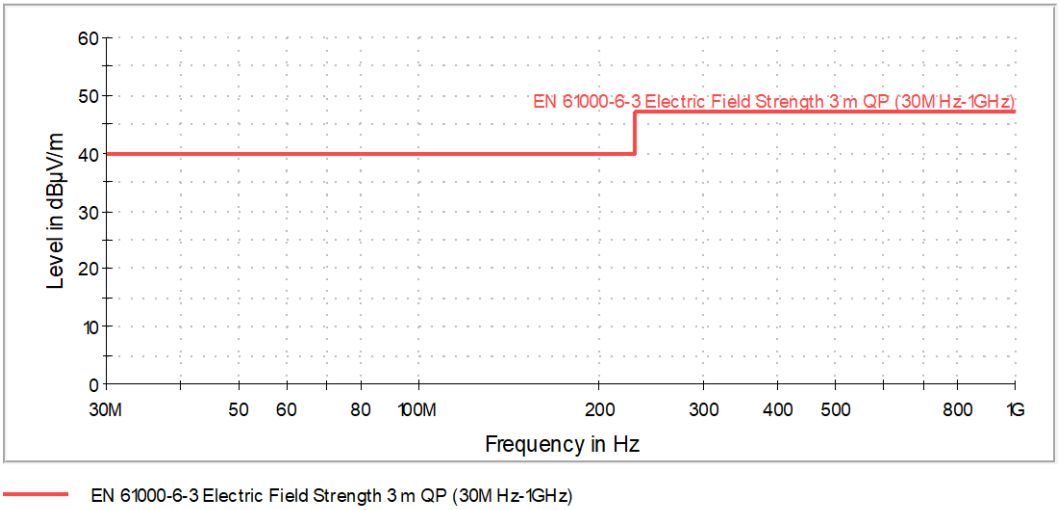


Fig. 7: Limit line example for frequency range 30 – 1000 MHz

NOTE: Limit lines for different measuring

The standardized measuring distance between DUT and antenna are 3 m, 5 m (OATS measurement), 10 m or 30 m. If the limit line is given by the standard for the defined distance (for example 10 m), there is possible to recalculate the limit line for E-field according to E-field properties – the intensity decreases by 20 dB/decade with increasing distance. For example, if the limit equals to 30 dBµV/m for 10 m distance than the re-calculated value for 3 m distance is 40 dBµV/m.

- **Conducted emissions** are almost always measured like a disturbance voltage or current in the frequency range 9 kHz – 30 MHz using a transducer:
    - Artificial network AN or line impedance stabilization network LISN which is connected to the voltage path without affecting of the operation of DUT,
    - Current probe in other cases.

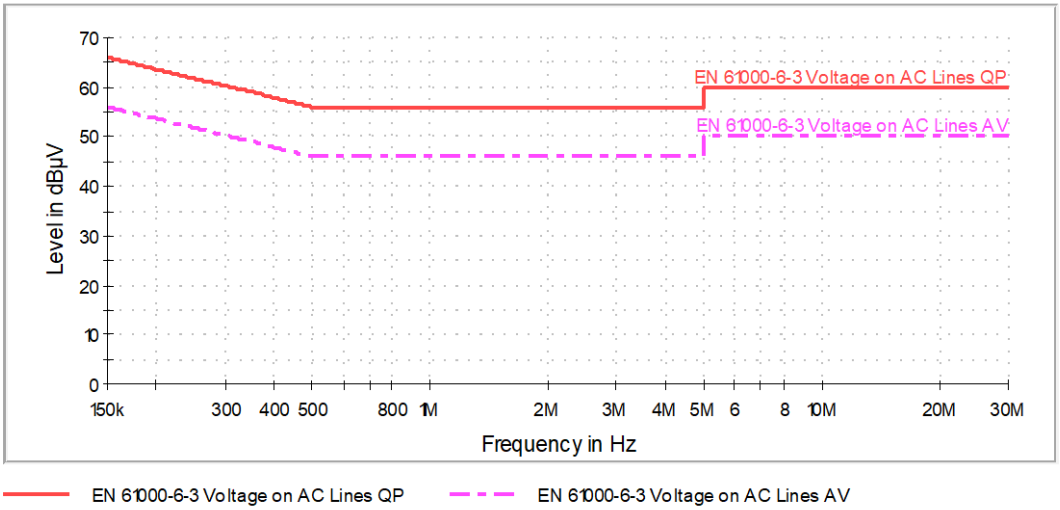


Fig. 8: Example of limit lines for disturbance voltage in the frequency range 150 kHz – 30 MHz

- **Low frequency emission** – especially measuring of voltage distortion of higher harmonics, measuring of harmonic currents (up to fortieth harmonic) or flicker measuring (for device which switch the power to the load).

4.2 Immunity testing

As with emission measurements, all interfaces of the DUT must be tested for electromagnetic susceptibility (immunity testing). There are a number of standards that describe the methods and especially the tests levels at which the interfaces must be tested.

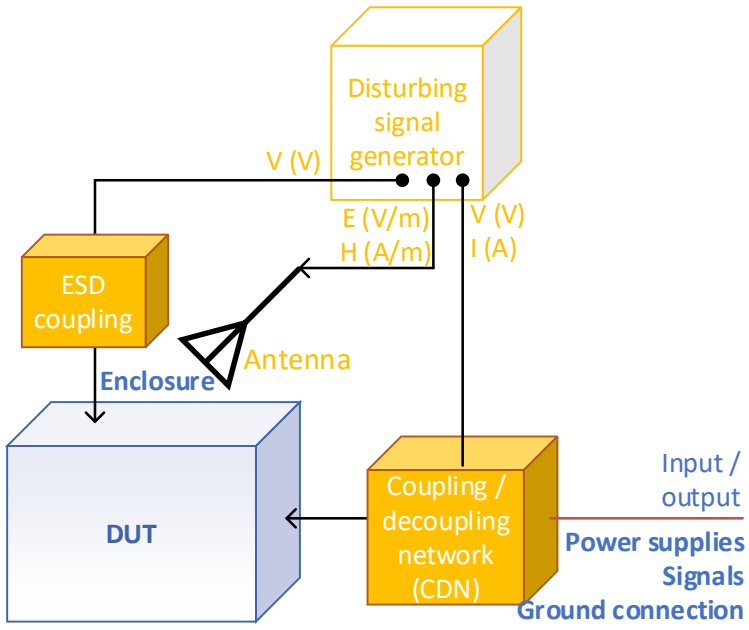


Fig. 9: Electromagnetic susceptibility testing of DUT

The electromagnetic susceptibility test of DUT from Fig. 9 can be divided to:

- **Enclosure tests** – there are usually performed:
    - electrostatic discharge (ESD) immunity test (air discharge for non-conductive enclosures and direct discharge for conductive enclosures),
    - radiated, radio-frequency, electromagnetic field immunity test in the frequency ranges 80 MHz – 1 GHz and 1.4 GHz – 6 GHz,
    - power frequency magnetic field immunity test,
- **tests of power supply input / output** – there are usually performed:
    - electrical fast transient / burst immunity test,
    - surge immunity test,
    - immunity to conducted disturbances, induced by radio-frequency fields (commom mode),
    - voltage dips, short interruptions and voltage variations immunity tests,
- **tests of signal input / output** – there are usually performed:
    - electrical fast transient / burst immunity test,
    - surge immunity test,
    - immunity to conducted disturbances, induced by radio-frequency fields (commom mode),

The performance criterion is the result of each immunity test – it shows the DUT behaviour during (and after) the test. The performance criteria for the DUT are defined by the standard – they are mostly marked by capital letters A, B, C, D:

- **Performance criterion A:** Normal performance within limits specified by the manufacturer, requestor or purchaser.
- **Performance criterion B:** Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention.
- **Performance criterion C:** Temporary loss function or degradation of performance, the correction of which requires operator intervention.
- **Performance criterion D:** Loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss data.

5 Accredited emission measurement

A lot of legislative requirements must be fulfilled for accredited emission measurement – equipment used for the measurements, measuring setups and also the competencies of the testing laboratory. Only the accredited subject can perform accredited tests in the Czech Republic (accredited laboratory, or authorized/notification body). The accreditation according to the relevant standard and for requirement standards is granted by Czech Accreditation Institute (ČIA). The accredited subjects may perform also pre-compliance tests during the time of equipment development. All accredited measurements are based on standard-defined measuring setups which ensure (among other things) the repeatability of the measurement.

5.1 EMI receivers

The accredited measurement of conducted or radiated emission must be performed using EMI receiver. It is a specific type of stectrum analyzer – it has for example different (against commonly used spectrum analyzer) measurement settings, specific input circuits, detectors, response to the impulse input signals, bandwidth of the IF filter (-6 dB). The standard ČSN EN 55016-1-1 ed.4 [17] defines all parameters of EMI receivers (CISPR 16).

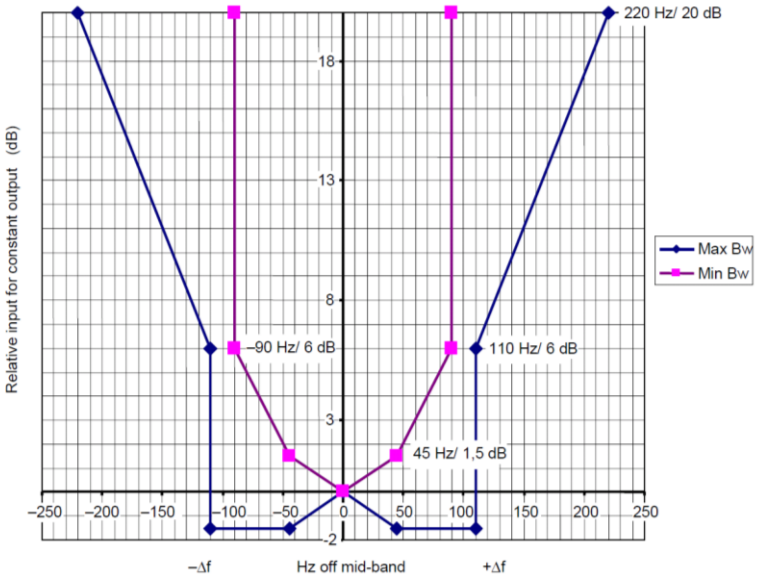


Fig. 10: IF filter bandwidth of EMI receiver, band A [17]

EMI receivers have following **detectors**:

- peak (PK),
- quazipeak (QPK),
- average (AVG, CISPR average),
- RMS (CIPR RMS).

At this time, no limit lines are defined in standards for RMS detector. In general, the voltage value of the peak detector is always higher than or equal to the voltage value of the quasi-peak detector, and it is again higher or equal to the voltage value of the average detector:

$$V_{PK} \geq V_{QP} \geq V_{RMS} \geq V_{AV}. \qquad ()$$

The following setting must be ised for EMI receiver measurements:

1. Set frequency range (depends on the standard), for example frequency range according to ČSN EN 61000-6-3 [18]:

Conducted emission	150 kHz – 30 MHz
Radiated emission	30 MHz – 1 (6*) GHz

* Depends on maximum inner frequency of the DUT (if f < 108 MHz, than f = 1 GHz)

2. Set bandwidth of IF filter (depends on measured frequency, given by CISPR 16):

Band	Frequency range	RBW (6 dB)
A	9 – 150 kHz	200 Hz
B	150 kHz – 30 MHz	9 kHz
C + D	30 – 1000 MHz	120 kHz
E	1 – 18 GHz	1 MHz

3. Set frequency step for measurement (there is not sweep time, but there is defined a frequency step – after measurement at one frequency, EMI receiver retunes about one frequency step and performs the measurement again, …):

$$\Delta f \leq \frac{1}{2} RBW \text{ (Hz)}. \qquad ()$$

4. Set the dwell time (measurement time) (depends on frequency and detector),

Band	Frequency range	Min dwell time
A	9 – 150 kHz	10 ms
B	150 kHz – 30 MHz	0,5 ms
C + D	30 – 1000 MHz	0,06 ms
E	1 – 18 GHz	0,01 ms

POZN: minimum dwell time for band (from fmin to fmax):

Band	Frequency range	PK (fmin – fmax)	QPK (fmin – fmax)
A	9 – 150 kHz	14,1 s	2820 s = 47 min
B	150 kHz – 30 MHz	2,985 s	5970 s = 1h 39 min
C + D	30 – 1000 MHz	0,097 s	19400 s = 5 h 23 min

5. Set detector type (depends on used standard), for example according to ČSN EN 61000-6-3[18]:

Conducted emission	150 kHz – 30 MHz	QP + AVG
Radiated emission	30 MHz – 1 GHz	QP
Radiated emission	1 – 6 GHz	PK + AVG

NOTE: superheterodyne vs. FFT EMI receivers

A lot of modern EMI receivers use Fast Fourier Transformation (FFT) – we speak about time domain measurement – the digital signal processing is used behind the front-end of the receiver (very simply put) (ie. behind the mixer).

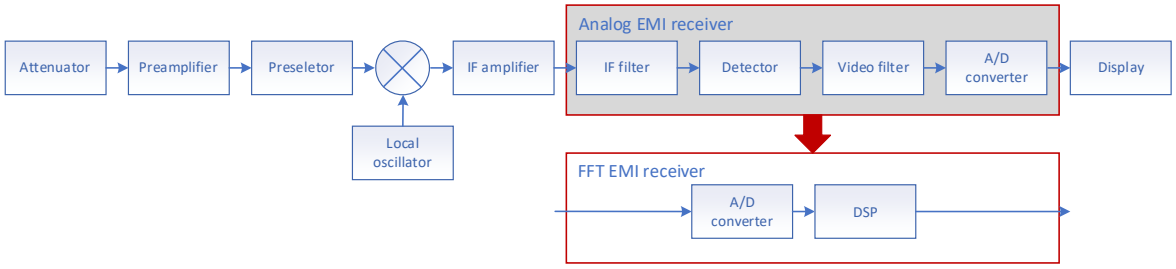


Fig. 11: Simplified block diagram of EMI receivers

The parallel measurements and calculations are performed in the EMI receiver during the measurement – each one for one time window (there is necessary their overlapping, see the following figure). The result is really fast measured spectrum (with defined frequency range) for all detector types including QP detector – the measurement time depends on the computational power of the device – whole spectrum can be measure almost as fast as one frequency point in the frequency domain. This FFT measuring frequncy range can be called for example FFT BW.

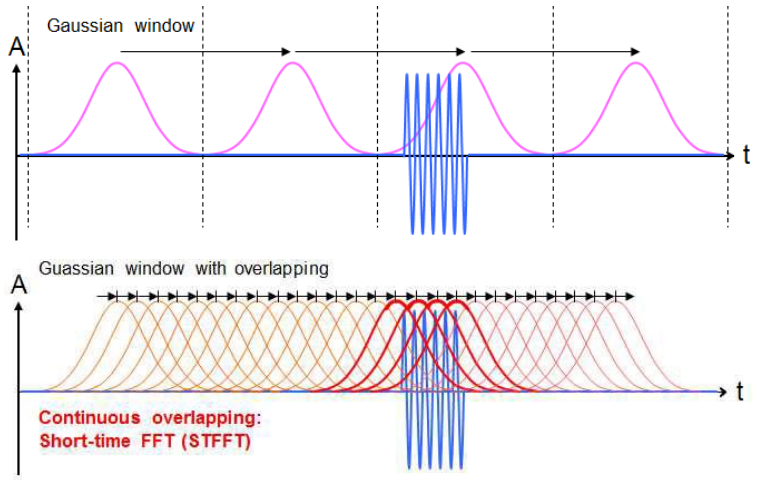


Fig. 12: Překrývání oken [32]

For example, EMI receiver R&S ESR7 has following FFT BW in the time domain: [from ESR7 specification]:

Time domain scan [1]		
Frequency segment processed in parallel	f < 7 GHz	
	RBW = 200 Hz	0.66 MHz
	RBW = 9 kHz	30 MHz
	RBW = 120 kHz	24.6 MHz
	RBW = 1 MHz	25.6 MHz
	f ≥ 7 GHz	
	RBW = 200 Hz	0.66 MHz
	RBW ≥ 9 kHz	10 MHz
FFT overlap factor		≥ 93 %

5.2 Accredited conducted emission measurement

The conducted emission measurement is based on measuring of the interference signal (voltage or current) by the EMI receiver using suitable transducer. The transducer type is defined especially by the possibility of its connection to the measured circuit – if there is not possible connect the transducer directly to the circuit (for example due to too high voltage on the wires or the transmitted signals could be influenced by transducer), there is possible to use contactless method – current measurement. All following measurement setups are defined according to the standard ČSN EN 55016-2-1 [19] and they are performed at the test site.

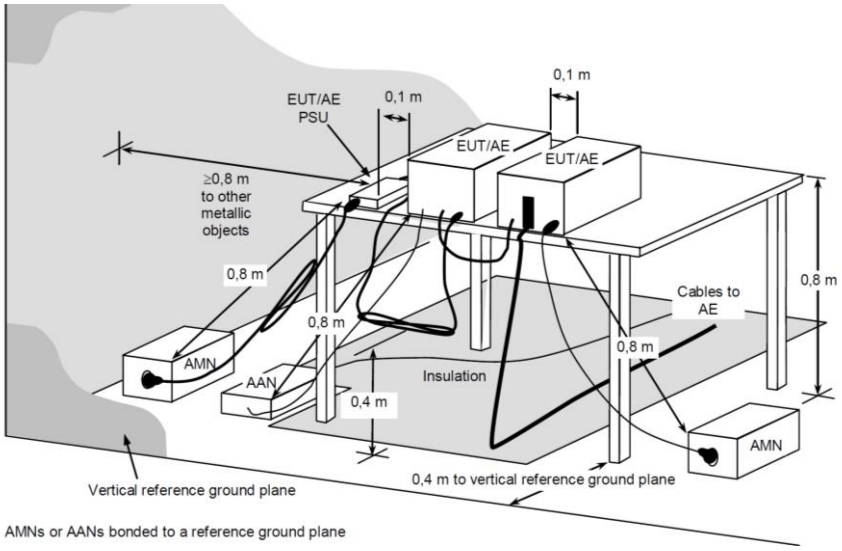


Fig. 13: Test site configuration for conducted emission measurement [19]

The final value of interference voltage equals to sum of measured voltage, attenuation of transmission line (including attenuation of transducer, pulse limiter, cables, etc.)

5.2.1 Measurements with artificial network

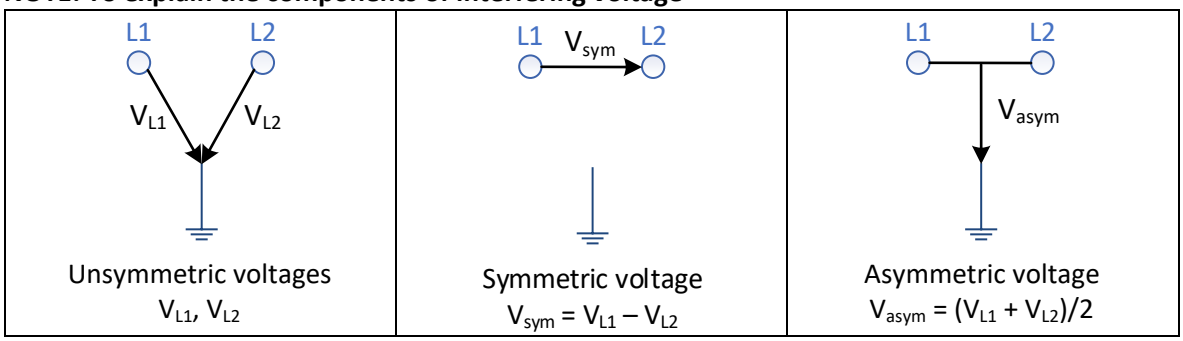
Artificial network – AN, sometimes are also called artificial mains network AMN or line impedance stabilization network – V-LISN is transducer that connect the disturbance signal to the EMI receiver. The main goal of AN is to define the impedance for measurement (in terms of repeatability of measurements) and suppress possible the interference from the power supply (mains, DC, signal, etc.). Three basic types exist in the terms of various components of disturbance voltage measurement:

- V AMN (V-LISN) – measuring of unsymmetric voltage,
- delta AMN (Δ AMN) – measuring of symmetric and asymetric voltages,
- Y AN (AAN – asymmetric artificial network) – measuring of asymetric voltage on (un)shielded symmetrical line.



Fig. 14: V-LISN (left) and Δ LISN [web Rohde&Schwarz and Schwarzbeck]

NOTE: To explain the components of interfering voltage



Definitions from CISPR 16-2:
1.3.10: **common mode (asymmetrical disturbance voltage)** – the RF voltage between the artificial midpoint of a two-conductor line and reference ground, or in case of a bundle of lines, the effective RF disturbance voltage of the whole bundle (vector sum of the unsymmetrical voltages) against the reference ground measured with a clamp (current transformer) at a defined terminating impedance.
1.3.12: **differential mode voltage; symmetrical voltage** – the RF disturbance voltage between the wires of a two conductor line
1.3.14: **unsymmetrical mode (V-terminal voltage)** – the voltage between a conductor or terminal of a device, equipment or system and a specified ground reference. For the case of a two-port network, the two unsymmetrical voltages are given by:
a) the vector sum of the asymmetrical voltage and half of the symmetrical voltage; and
b) the vector difference between the asymmetrical voltage and half of the symmetrical voltage.

Definitions from IEC 50 (161):
161-04-08: **differential mode voltage; symmetrical voltage** – the voltage between any two of specified set of active conductors.
161-04-09: **common mode voltage; asymmetrical voltage** – the mean of the phasor voltages appearing between each conductor and a specified reference, usually earth of frame.
161-04-11: **symmetrical terminal voltage** – differential mode voltage, measured by means of a delta networks at specified terminals.
161-04-12: **asymmetrical terminal voltage** – common mode voltage measured my means of a delta network at specified terminals.
161-04-13: **V-teminal voltage** – terminal voltage, measured between a mains conductor and earth, in a V-network

5.2.2 Measurements with voltage probe

The voltage probe is usually used for measurement where is not possible use AN (in-situ measurement, high voltage circuits, etc.). Measurements with voltage probes are distorted by undefined impedance of power supply and by low sensitivity of the probe. The main advantage is possibility to connect the probe directly to the wires (teminals). There is measured voltage between conductor and earth – it is unsymmetrical voltage.



Fig. 15: Voltage probe [web Narda]

5.2.3 Measurements with current probe

Current probes (current transformers) can measure all components of disturbing current – if they are correctly connected to the circuit. Some standards define current probe measurements, some standards do not – there is possible recalculate the defined voltage limit to current limit. (for example, ČSN EN 55011, tab. 3: V (dBµV) = I (dBµA) + 44 dB).



Fig. 16: Current probe [web Rohde&Schwarz]

5.3 Accredited radiated emission measurement

The radiated emission measurement is based on the measurement of antenna terminal voltage using EMI receiver and it is follows by evaluation (conversion) of the measured voltage to the intensity of the electric (or magnetic) field. All following measurement setups are defined in ČSN EN 55016-2-3 [20].

5.3.1 Measurements with antennas

The measurement is standardly performed in test site:

- open area test site – OATS,
- semi anechoic chamber – SAC,

- fully anechoic room – FAR,
- TEM waveguide,

and there is a defined distance between the antenna and DUT. SAC and FAR are commonly used for measurement – there are the lowest level of the background noise. TEM waveguide is used for small, battery powered devices.

NOTE: Measuring distance
The distance between antenna and DUT should be chosen in far field zone, ie the distance $d >> (\lambda/2\pi)$ and $d \geq (2D^2/\lambda)$, where d is the measuring distance and D represents maximum DUT dimension including cables. H-field measurement can also be performed in near field. The ideal measuring distance is ussually not possible use for in-situ measurements – there is necessary to convert the measuring results according to the real measuring distance – there is not possible used only the convertion factor 20 dB/dec.

The highest interference is sought during the measurement – the highest intensity of electric field – from this reason, the hight of the antenna must be changing from 1 m to 4 m (above the reference ground plane), the polarization must be changing (horizontal – vertical) and also the azimuth of DUT – antenna must be changing using turntable.

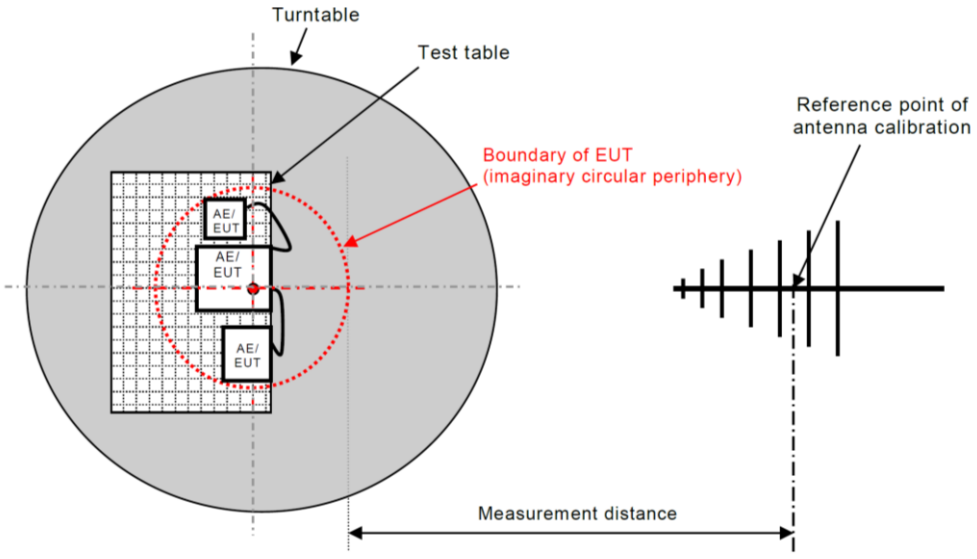


Fig. 17: Definition of measuring distance [20]

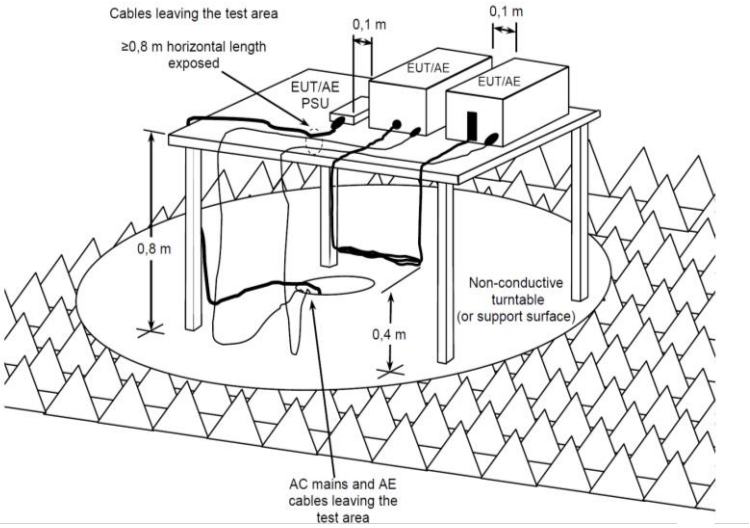


Fig. 18: Example of the test setup for device placed on the table [21]

The frequency range of the antenna is usually large – usually across few decades – the wideband antennas must be used. The commonly used antennas are:

- dipole antennas,
- biconical antennas,
- log-per antennas,
- double-ridged horn antennas.

Dipole antennas are used for measurement electric (usually active rod antenna) and magnetic (active loop antenna) field. The frequency range can be between 9 kHz – 30 MHz, especially in the transport industry (automotive or railway.


Fig. 19: Examples of dipole antenass [web Rohde&Schwarz]

Biconical antennas are principally based on dipole antennas, the bandwidth is increased by the increasing width of active elements (dipoles). The frequency range can be approx. 20 – 300 MHz

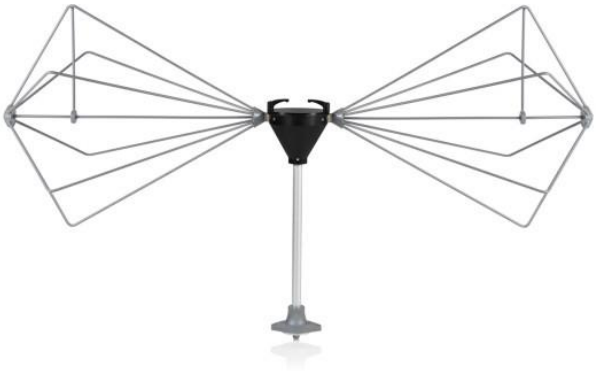


Fig. 20: Example of biconical antenna [web Rohde&Schwarz]

Log-periodical antennas represents antennas where are suitably folded dipoles – the longest dipole determines the lowest frequency and the shortest dipole determines the highest frequency of the antenna. The frequency range can be aroun 200 – 6000 MHz.

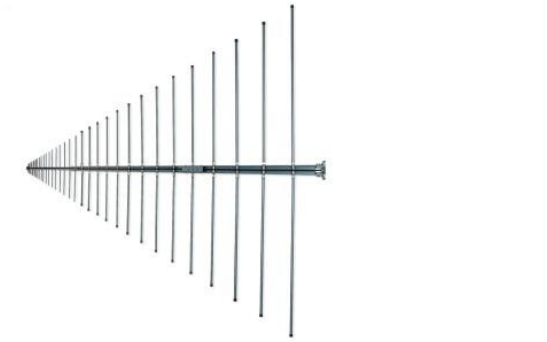


Fig. 21: Example of log-per antenna [web Rohde&Schwarz]

Double-ridged horn antennas are wideband antennas, the frequency rance can be from 300 to 18 000 MHz (some tyte – not for EMC measurement have maximum frequency 40+ GHz.



Fig. 22: Example of double-ridged horn antenna [web Rohde&Schwarz]

Note: Double-ridged horn antenna vs. horn antenna

Double-ridged horn antennas are based on horn atennas – but double ridge increase the frequency range of the antenna (aprox. 10x). Horn antennas are usually narrowband and there is necessary to use more antennas for EMC measurement. Horn antennas are used like as transmitting/ receiving antennas for telecommunication services with frequency up hunderds GHz.

Some antenna types are composed from basic antenna types – then we speake about **combined antennas**. Biconical and log-per antennas are most often combined together – the frequency range can be around 30 – 6000 MHz.

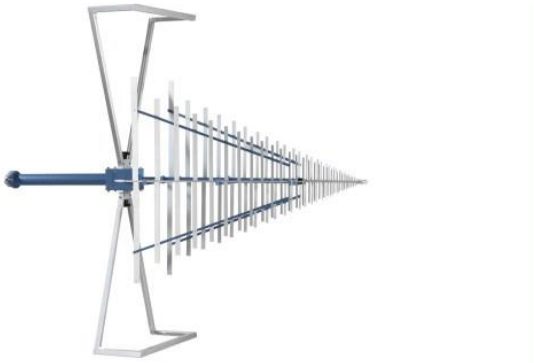


Fig. 23: Example of a combined antenna [web Rohde&Schwarz]

The final value of E-field is composed on sum of measured voltage on antenna + antenna factor + cable attenuation:

$$E\left(\frac{dB\mu V}{m}\right) = V_{measured}\ (dB\mu V) + AF\left(\frac{dB}{m}\right) + A_{transmmision\ line}\ (dB). \qquad ()$$

Similar equation should be used for H-field.

NOTE: Convertion E-field to H-field

If the measurement is perfomed in the far-field, ie. The wave impedance equals to:

$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \cong 377\ \Omega$ (vectors of E and H field are perpendiculary), there is possible to make convertion:

H (µA/m) = E (µV/m)/377 Ω, respectively if we calculated directly in dB:

H (dBµA/m) = E (dBµV/m) - 51,5.

NOTE: Measurement uncertainties

Everyone part of measurement chain represents some uncertainty for final measured value. From this reason, the expanded uncertainty of the measurement chaim must be calculated (it equals to sum of measurement uncertainty of EMI receiver, uncertainty of antenna calibration, cable

measurement uncertainty, etcThe maximum values of the expanded uncertainty are defined in the standards family CIPR 16. If the expanded uncertainty exceeds the standard defined value, then the difference between them must be eliminated, for example in the measuring software.

Examples of expanded uncertainties for EMI receiver ESR 7:

Frequency range (MHz)	Combination	Type	U_{lab} (dB)	U_{cispr} (dB)
0,009 - 0,15	V-LISN	ESH2-Z5	3,31	3,8
0,15 - 30	V-LISN	ESH2-Z5	3,31	3,4
0,009 - 30	Voltage probe	SHC1-1000	3,16 *1)	2,9
0,15 - 30	Current probe	EZ-17	3,3 *1)	2,9
0,15 - 30	antenna	HFH2-Z2	3,16	3,3
30 - 1000	antenna	BC-01, LP-02, BTA-M	3,84	6,3
1000 - 6000	antenna	BBHA9120E	3,84	5,2

*1) $U_{lab} \geq U_{cispr}$, eliminated by SW

The examples of antenna factors are shown in Fig. 24. These types of antennas are presented:

- combined antenna BTA-M (biconical + log-per, 30 – 3000 MHz),
- biconical antenna BC-01 (30 – 300 MHz),
- log-per antennaLP-02 (300 – 2700 MHz),
- double-ridged horm antenna BBHA9120A (450 – 6000 MHz).

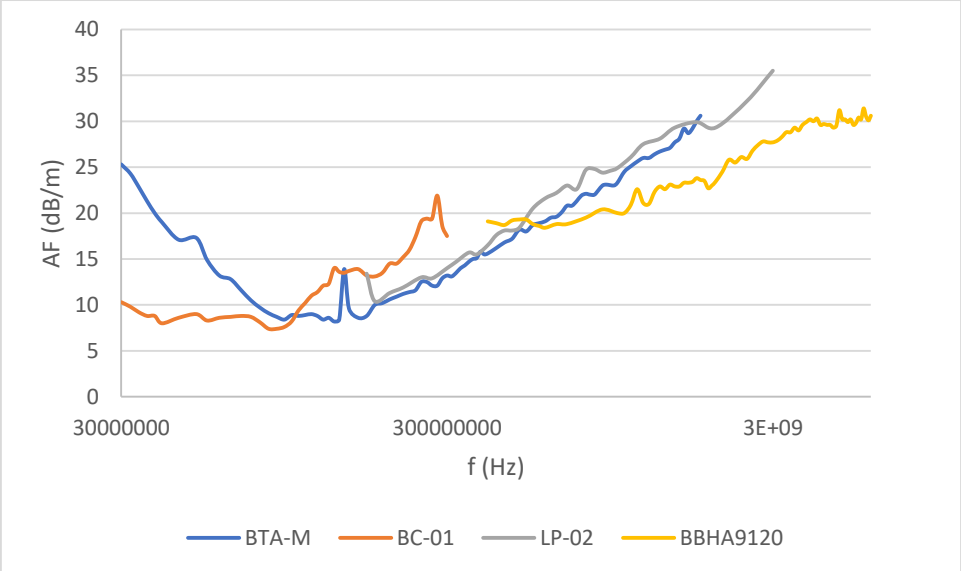


Fig. 24: Antenna factor of different antennas 30 MHz – 6 GHz

The transmission line attenuation equals to attenuation of all connected cables and their interconnection – usually is necessary to use bulkhead connector on the SAC or FAR wall. Examples of cable attenuation are shown in Fig. 25.

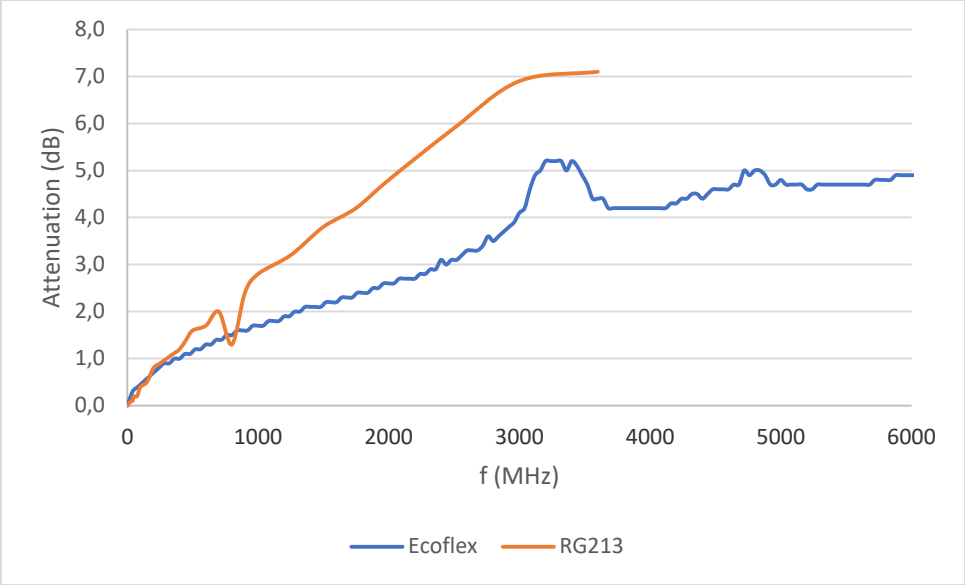


Fig. 25: Attenuation of different cable types 1 kHz – 6 GHz

5.3.2 Measurement with absorption clamp

This type of measurement is possible only for standard-defined device group. It is alternative method to the radiated emission measurement.



Fig. 26: Absorption clamp [web Schwarzbeck]

5.4 Measurement setups

The definition of the measurement setup is crucial for correct measurement. The setup is composed of all parts of the measurement chain, including all parameters of them. Fig. 27 shows measurement setup for conducted emission measurement – a V-LISN, a connecting cable, a pulse limiter and an EMI receiver are used here. Each part has defined correction table for the full frequency range of the measurement:

- V-LISN (for all wires),
- connection cable,
- pulse limiter.

Similar setups should be made for voltage or current probe measurements.

NOTE: pulse limiter (transient limiter)
Pulse limiter is necessary to use for non-antenna measurement. The pulse limiter has a two goal – the first one is over-voltage protection of the EMI receiver (or spectral analyser) input (short time protection against transients or ESD) and the second one is the attenuation of the input signal (usually 10 dB). If the frequency range of the measurement is ended at 30 MHz, the attenuation of the short connection cable between for example LISN and pulse limiter can be neglected (it is in range of tenths of dB).

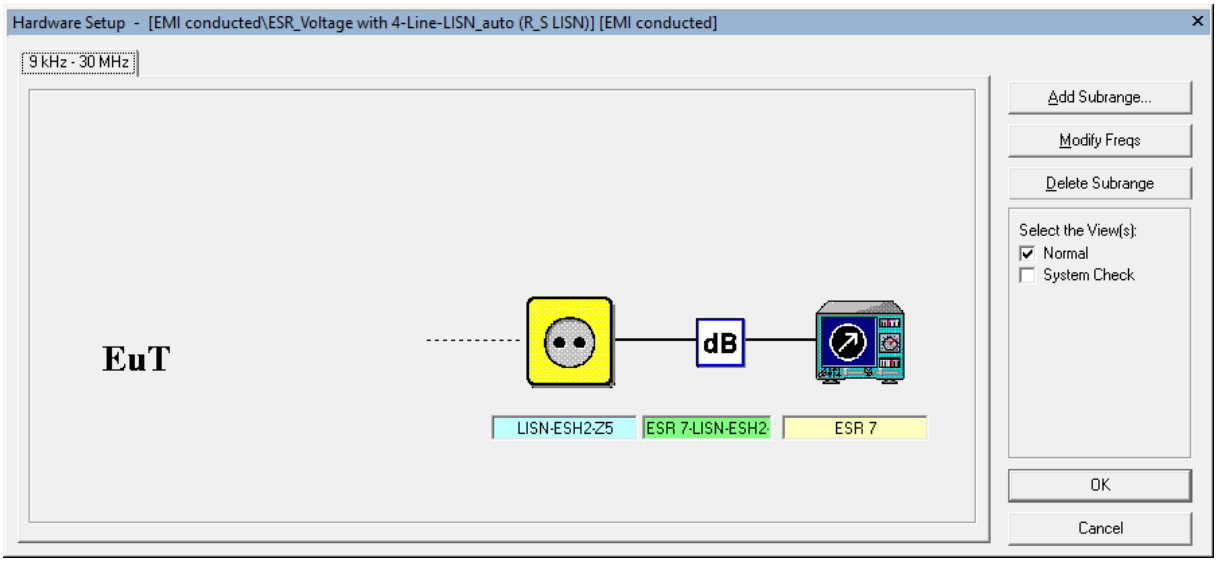


Fig. 27: Measurement setup for conducted emission measurement

Fig. 28 represents measurement setup for radiated emission measurement. It is composed of EMI receiver, connection cable and antenna. Two frequency ranges are used for two types of antenna (each of them with a different usable frequency range). The parameter antenna factor is really important due to calculation of final E(H)–field – it convert the measured voltage to the E(H)-field. The attenuation is not neglible for frequencies under 30 MHz and there is necessary to calculate with it everytime.

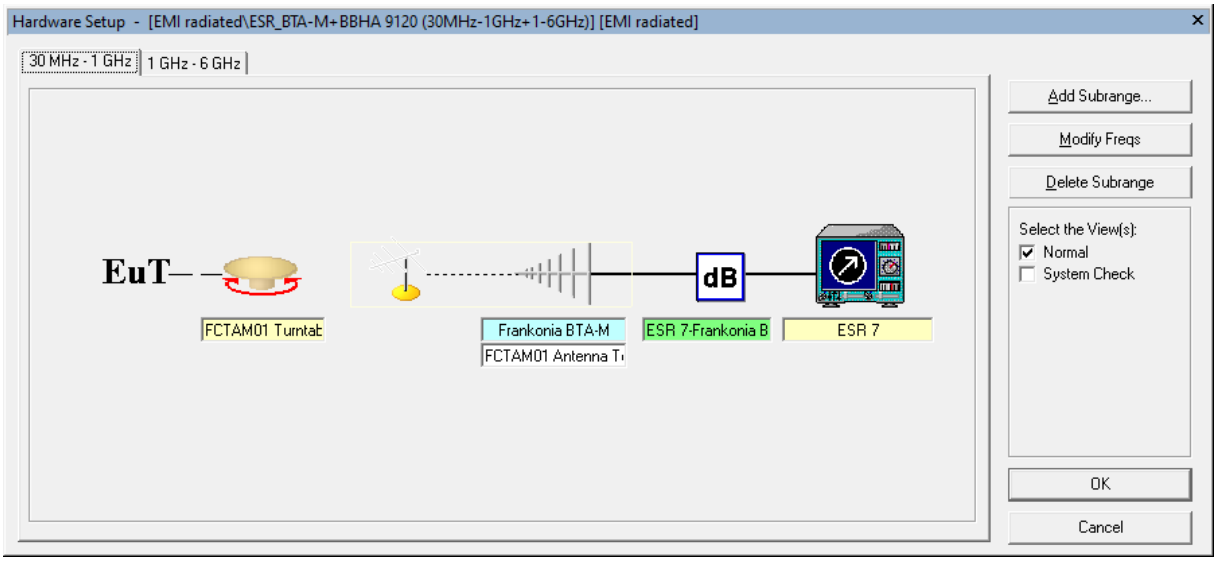


Fig. 28: Measurement setup for radiated emission measurement

The antenna tower and the turntable is also visible in Fig. 28 – the highest disturbing value from the DUT is sought during the measurement, ie. the hight (1 – 4 m above the reference ground plane) / polarization (horizontal - vertical) of the antenna is changing and the azimuth of the DUT relative to the antenna (0 - 360°).

5.5 Measurement evauation

CISPR 16 very often requires the quasi peak detector for measurement. The defined measuring time (min 1 s for each measurement frequency) does not allow to measure the whole frequency range using QPK detector due to the large time consumption. From this reason, the preview measurement (prescan) can be performed at first according to the CISPR 16. The peak detector is there used and the measurement time is relatively short. The measured PK values are compared with QPK limit (for defined standard), if some PK values exceed the limit (or is close to the limit), the representative number of frequencies is chosen for final (QPK detector) measurement. The final measurement is performed only at chosen frequencies – there is not necessarily to measure all exceeding peaks. The maxhold function in the software allows final evaluation of all partiar measurements – Fig. 29 represents SW setup for measurement evaluation; the 3-phase V-LISN is used – the maxhold value are sotred from PK prescans, then it is compared with limit in the SW and the final measurement is performed finally at relevant phase.

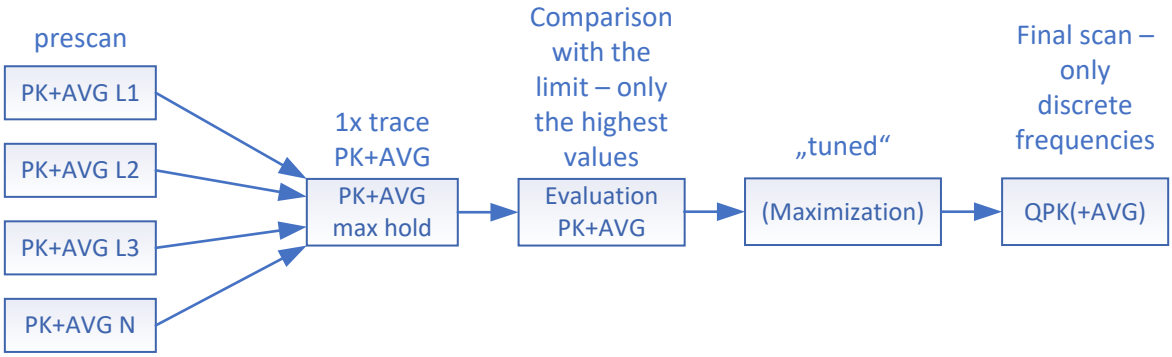


Fig. 29: Measurement with 3-phase V-LISN

The SW setup for measurement from Fig. 29 is shown at following pictures.

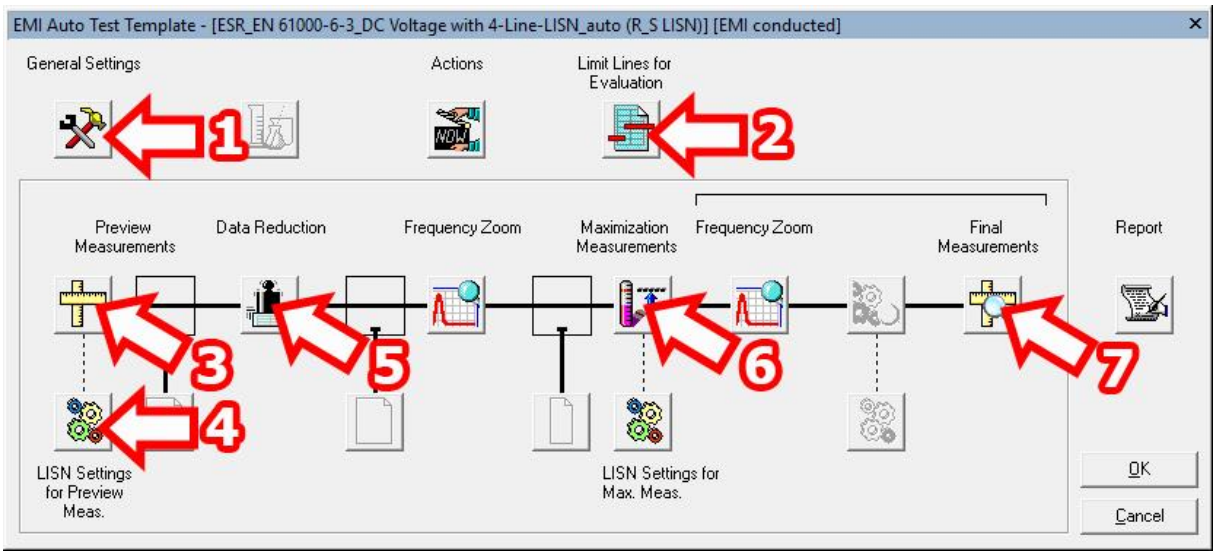


Fig. 30: Measurement with 3-phase V-LISN using SW R&S EMC32

The arrow 1 – General Settings – defines the measurement chain (see the Fig above). Arrow 2 – Limit Lines for Evaluation – sets defined limit lines for evaluation. Arrow 3 – Preview measurement – sets measurement properties – frequency range, RBW of EMI receiver, frequency step, dwell time, attenuation, etc.):

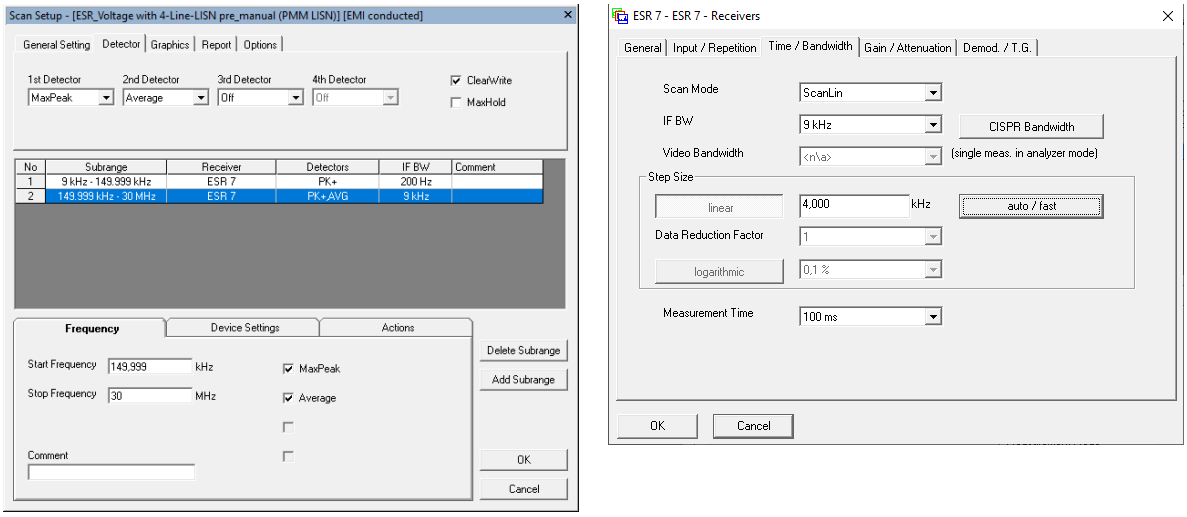


Fig. 31: EMI receiver settings for prescan

Arow 4 – Settings for Preview Meas. – defines each partial measurements “number of prescan” – for example for V-LISN:

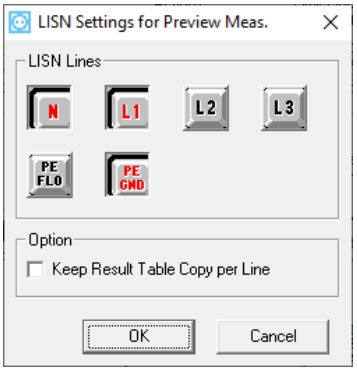


Fig. 32: V-LISN settings

Arrow 5 – Data Reduction – sets the evaluation with the limit line form maxhold values of prescans. The output is the table with discrete frequencies for following (or directly final) measurement.

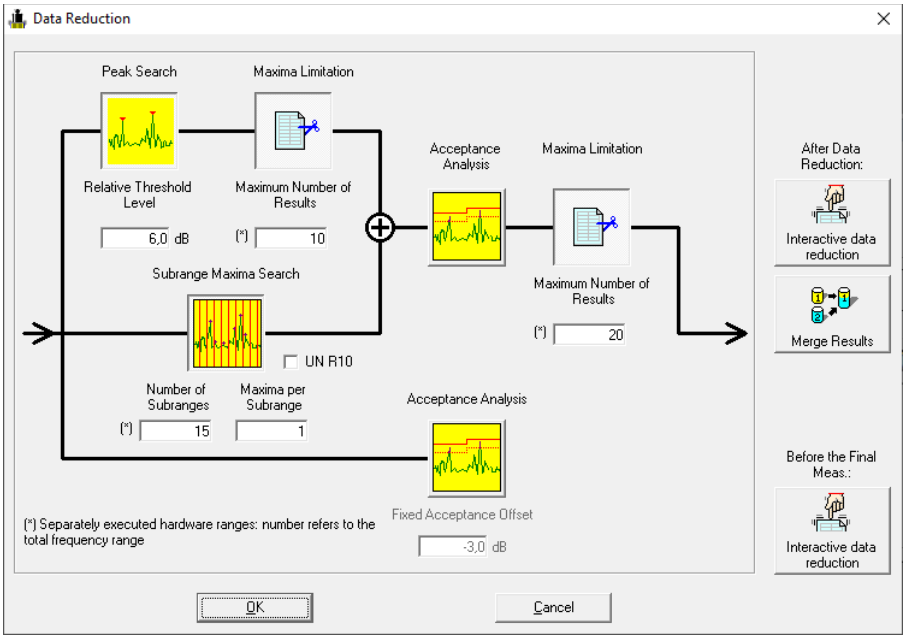


Fig. 33: Evaluation of measured (prescan) values with limit line(s)

Arrow 6 – Maximization – set parameters for frequency tuning of maximal disturbing value near the frequency from “Data Reduction” table. If the prescan setting is set correctly (for example with long measuring time for conducted emission measurement), it is not necessary to perform the maximization.

Arrow 7 – Final Measurement – sets (similary like arrow 3) measurement properties, especially the detector settings (for example QPK + AVG). The final measurement is performed only at descrete frequencies from “Data Reduction” table or at frequencies after Maximization measurement.

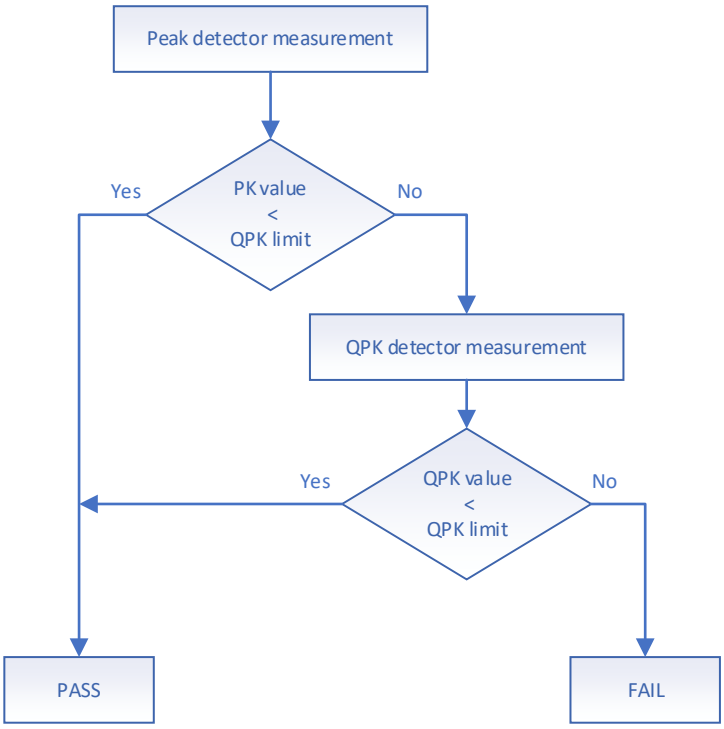


Fig. 34: Evaluation for quasipeak limits

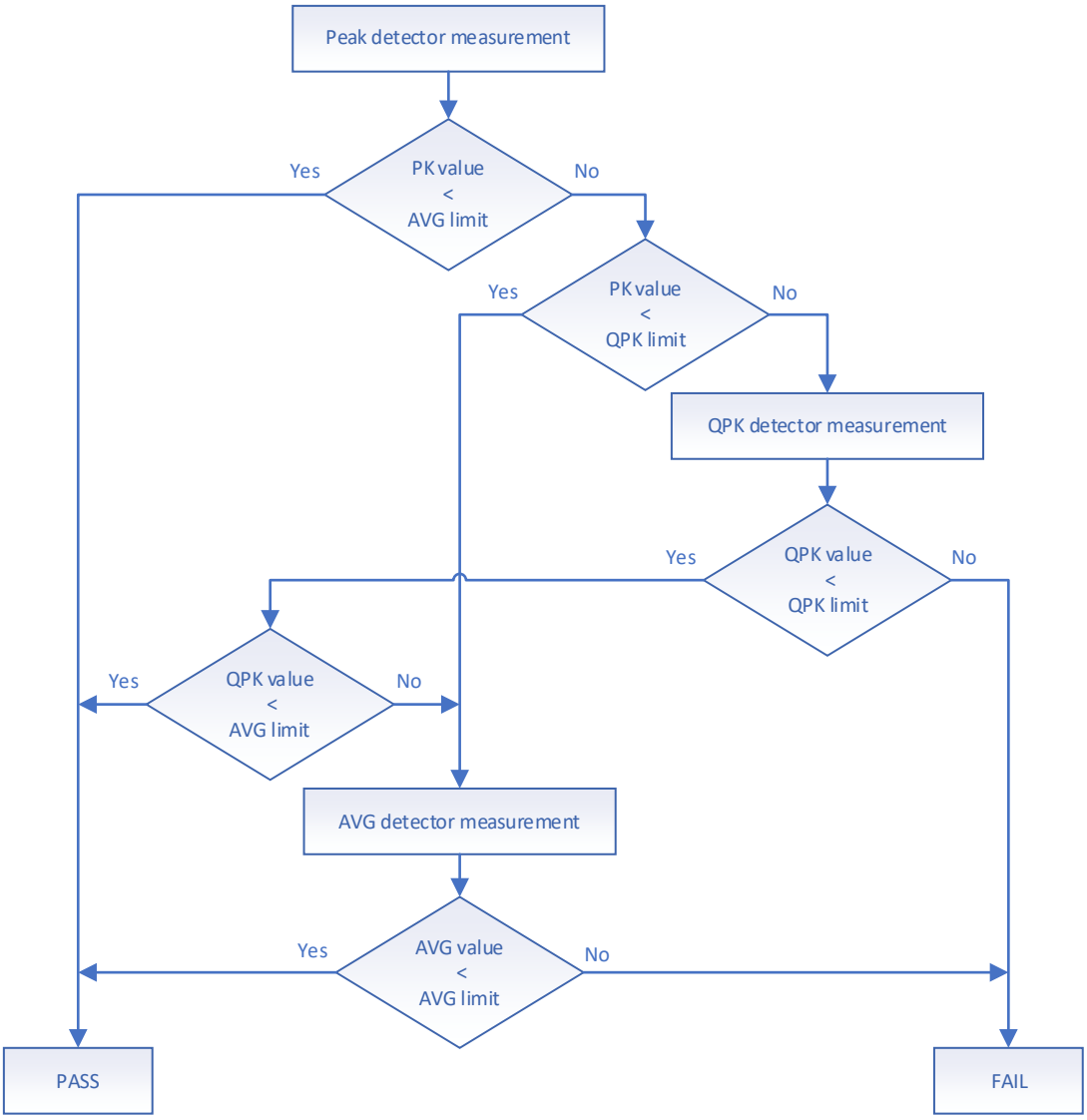


Fig. 35: Fig. 34: Evaluation for quasipeak and average limits

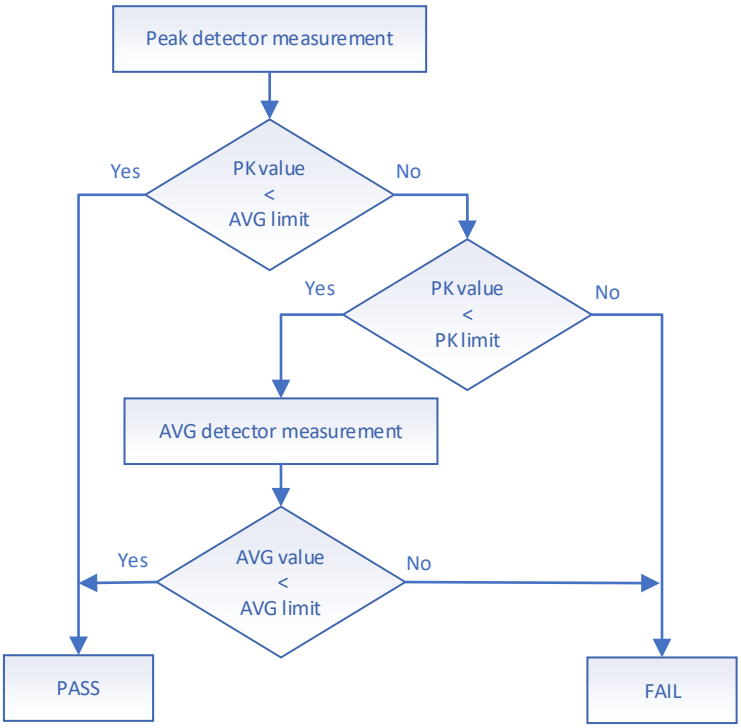


Fig. 36: Evaluation for average limit

6 Accredited susceptibility testing

The susceptibility (immunity) testing of DUT means to exposure the DUT to the external disturbances. The test site setting and testing levels (of disturbing signals) are defined by standards family ČSN EN 61000-4-X. **The test result** is determination of performance criterion that is based on observing of the DUT behaviour during (and after) the test.

The performance criterion is the result of each immunity test – it shows the DUT behaviour during (and after) the test. The performance criteria for the DUT are defined by the standard – they are mostly marked by capital letters A, B, C, D:

- **Performance criterion A:** Normal performance within limits specified by the manufacturer, requestor or purchaser.
- **Performance criterion B:** Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention.
- **Performance criterion C:** Temporary loss function or degradation of performance, the correction of which requires operator intervention.
- **Performance criterion D:** Loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss data.

The manufacturer (or importer) of the DUT is responsible for functionality of the DUT, including possible insignificant (ie permissible) effects of the disturbance signal on the equipment.

Test levels are described by numbers in the basic standards that define value of the disturbance signals (voltage level, intensity of the electic or magnetic field, …). These levels are defined to the environment in wich the device will be located.

NOTE: Selection of test level and performance criterion
The product standard defines the test level and performance criterion for defined DUT. If does not exist the product standard, the priority is on product family standard on the generic standard for typical environment of the DUT (if deos not exist the product family standard). The DUT met the standard, if the test result (achieved performance criterion after the test) is the same like by the standard defined criterion or better.

The coupling networks are usually used to connect the disturbing signal to the DUT (except the radiated immunity test, where some type of antenna is used). This coupling network usually contails also decoupling network – it suppress the disturbing signal in the direction of auxiliary equipment (power supply line, auxiliary signal generator, etc.). Then we speak about coupling / decoupling network – CDN.

NOTE: Is necessary to perform all tests?
It depends on the interfaces of the DUT – all test are defined by standard – and the standard defines (sometimes) some exceptions. It usually depends on the physical length of connected

wires – if the lenth is shorter than the standard defined value, then the test does not have to be performed. If the cable length is shorter than 3 m, then the 61000-4-4 and 61000-4-6 is not performed and if the length < 30 m and the cable do not leave the building then the test according to 61000-4-5 is not performed too.

6.1 Electrostatic discharge (ESD) immunity test

Test method: ČSN EN 61000-4-2

Test setup: The DUT is placed on the insulating support at (conducting) horizontal coupling plane. The standardized test signal from ESD generator is applied 10 times by a prescribed procedure at commonly available selected spots (impedance 150 Ω + 330 pF for home and industrial applications). The testing points correspond to the area that the operator may normally touch.

The coupling method for the disturbing signal:

- Contact discharge – applied to conductive surfaces of the DUT – the sharp test tip is directly connected to the DUT,
- Air discharge – applied to insulating surfaces of the DUT – when the round test tip approaches the DUT and moves away again,
- Coupling plane (horizontal or vertical) where the device is placed, for example, in switchboards, or it is placed next to conductive surfaces.

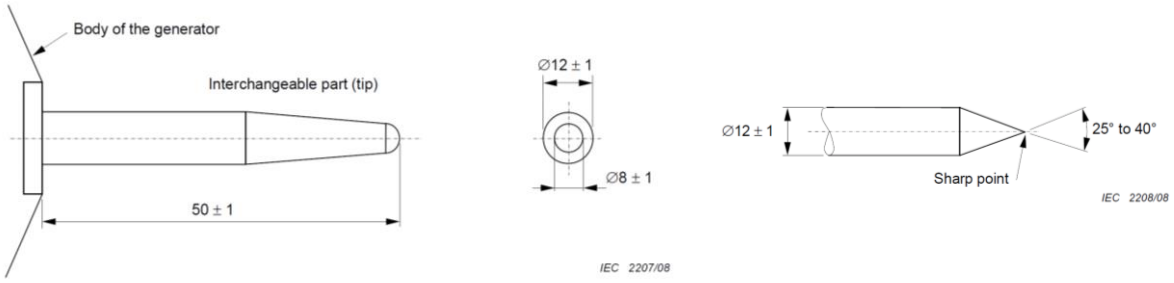


Fig. 37: Round and sharp test tips of ESD generaor [25]

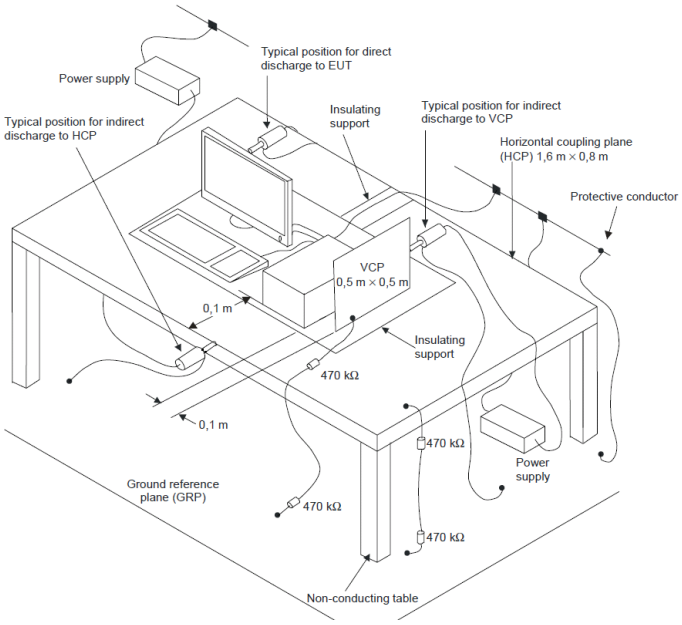


Fig. 38: Test setup according to ČSN EN 61000-4-2 [25]

Test levels:

Contact discharge		Air discharge	
Level	Test voltage	Level	Test voltage
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
x *1)	special	x *1)	special
*1) test level x can be any other value lower, higher or between other levels.			

Waveform of the output current of the ESD generator:

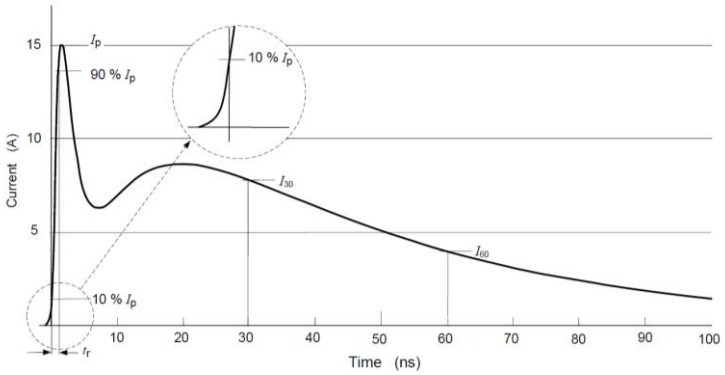


Fig. 39: Ideal current waveform for 4 kV contact discharge [25]

6.2 Radiated, radio-frequency, electromagnetic field immunity test

Test method: ČSN EN 61000-4-3

Test setup: During the test, the subject under test is placed in an anechoic chamber on a wooden table 0.8 m above the reference ground plane, in the distance 3 m from the antenna. The RF signal in the frequency range 80 – 1000 MHz and 1400 – 6000 MHz is modulated by a 1 kHz sine wave with a modulation depth of 80%. The sweep rate does not exceed 1% of the previous frequency; the dwell time is minimaly 0.5 s. The DUT should be tested from four sides.

The coupling method for the disturbing signal: E-field in the open space.

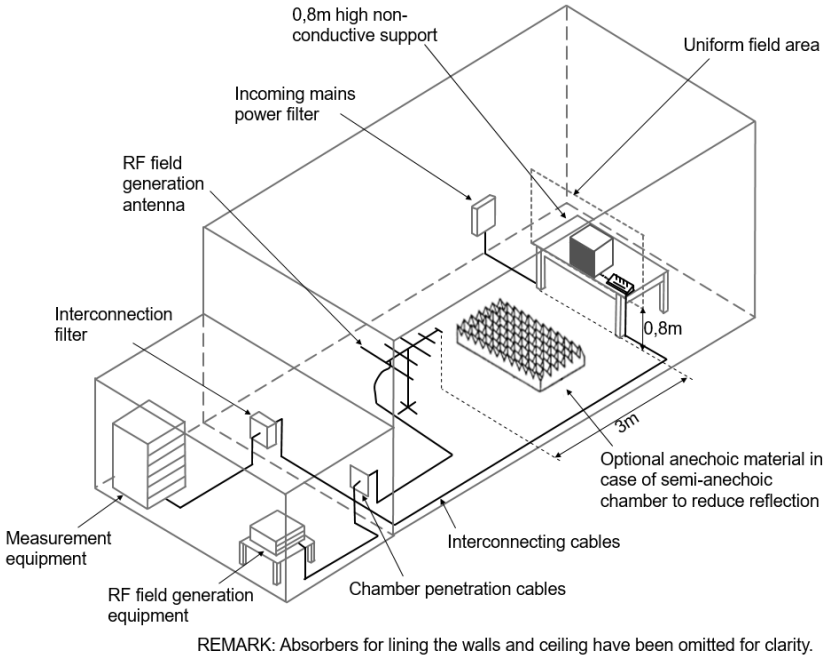


Fig. 40: Test setup according to ČSN EN 61000-4-3 [26]

Test levels:

Level	E-field intensity (V/m)
1	1
2	3
3	10
4	30
x *1)	Special
*1) unlimited, can be given in the product standard.	

Waveform of the disturbing signal:

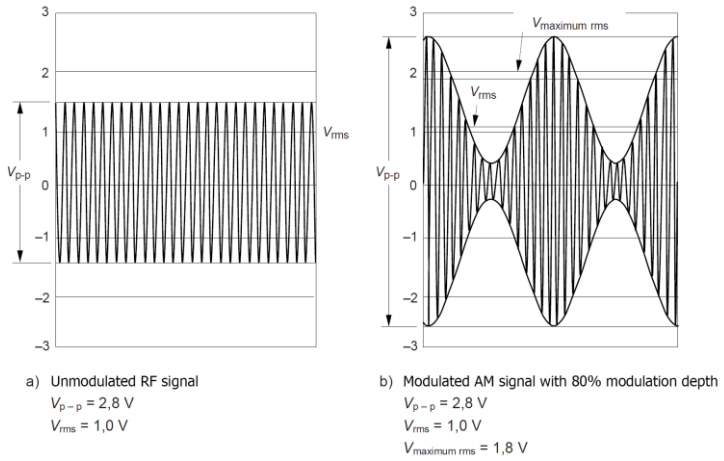


Fig. 41: Unmodulated (calibration) and modulated (test) signals [26]

NOTE: Other modulation than AM
There are different modulations – pulse modulation, FM – especially for testing of DUT at telecommunication services frequencies (ie. LTE, GSM, BT, Wi-Fi, etc.) [ČSN EN 60601-1-2 ed.3 – Zdravotnické elektrické přístroje], nebo v automotive.

6.3 Electrical fast transient / burst immunity test

Test method: ČSN EN 61000-4-4

Test setup: The DUT is placed on the 10 cm high insulating support on the table with RGP. The minimal testing time is 1 min for both polarities of the disturbing signal, which is applied using a suitable coupling.

The coupling method for the disturbing signal:

- CDN: The disturbing signal is connected via coupling C = 33 nF.

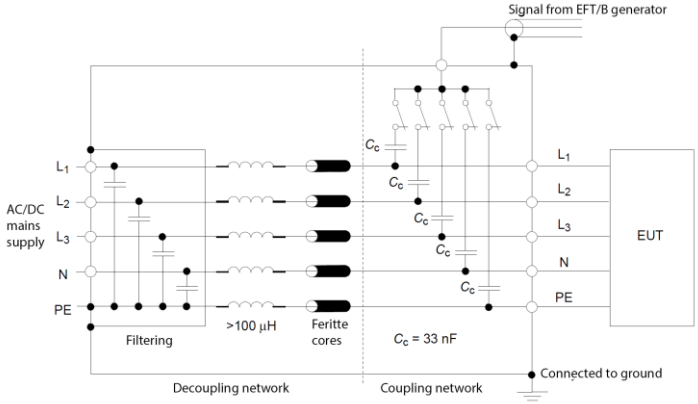


Fig. 42: Example of CDN for power lines [27]

- Capacitive clamp: If is not possible to use CDN (for example, if the usable signal is influenced by CDN, etc.), the 1 m length capacitive clamp is used.

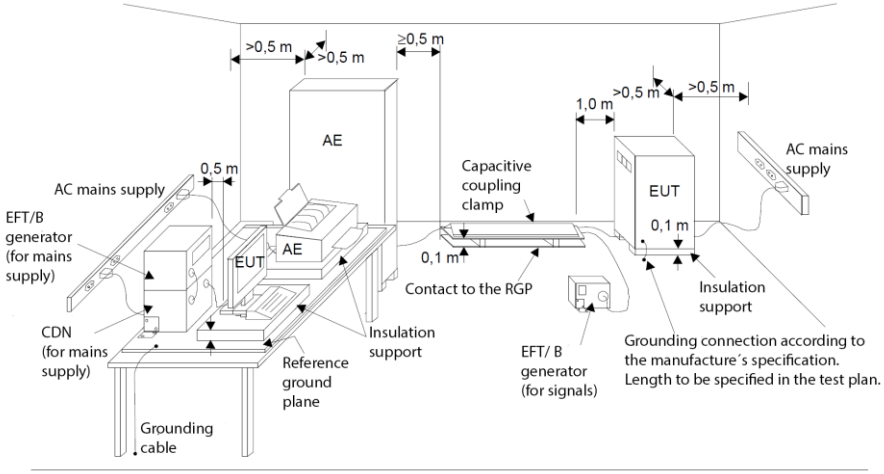


Fig. 43: Test setup example according to ČSN EN 61000-4-4 [4-4]

Test levels:

Output voltage without load				
Level	Power supply, ground connection I/O		Signals and control I/O	
	Test voltage (kV)	$f_{repetition}$ (kHz)	Test voltage (kV)	$f_{repetition}$ (kHz)
1	0,5	5 or 100	0,25	5 or 100
2	1	5 or 100	0,5	5 or 100
3	2	5 or 100	1	5 or 100
4	4	5 or 100	2	5 or 100
x *1)	special	special	special	special
*1) test level x can be any other value lower, higher or between other levels.				

Waveform of the disturbing signal:

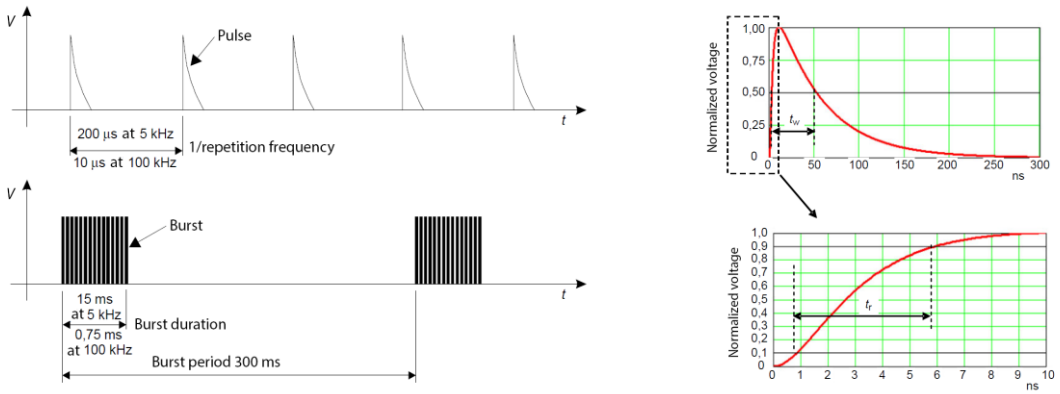


Fig. 44: Voltage waveform of 5/50 ns signal [27]

6.4 Surge immunity test

Test method: ČSN EN 61000-4-5

Test setup: The test signal (combined wave 1.2/50 + 8/20 μs) of both polarities is applied by a suitable coupling network to the specified interfaces. Five pulses for each polarity is usually used for defined angles (synchronization with AC line at 0 °, 90 °, 180 °, 270 °).

The coupling method for the disturbing signal:

- between the power supply lines – 18 μF,
- between power supply line and ground – 9 μF + 10 Ω,
- between telecommunication line and ground – 40 Ω + 0,5 μF,
- 18 μF for shielded cable.

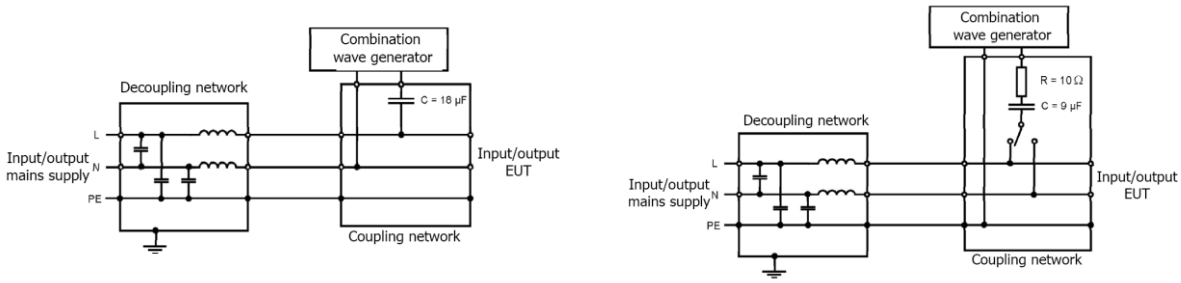


Fig. 45: CDN examples for power line [28]

Test levels:

Level	No-load test voltage (kV)	
	Line to line	Line to ground
1	NA	0,5
2	0,5	1
3	1	2
4	2	4
x *1)	Special	Special
*1) test level x can be any other value lower, higher or between other levels.		

Waveform of the disturbing signal:

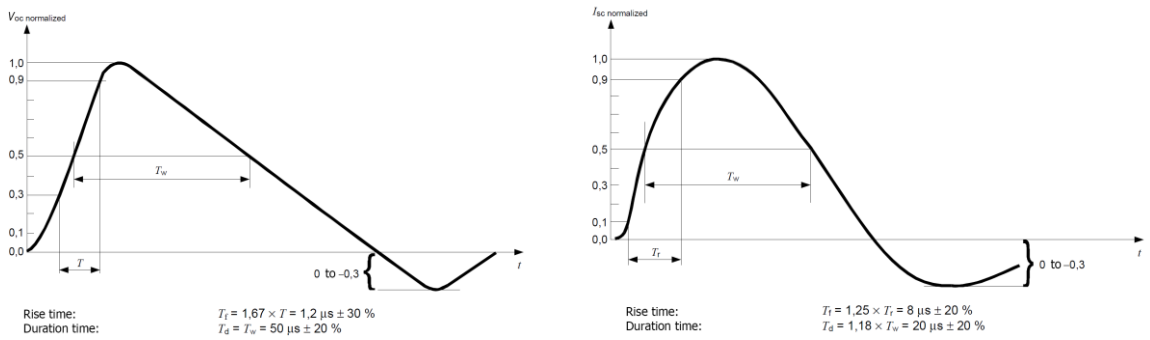


Fig. 46: No-load voltage and short circuit current of 1.2/50 + 8/20 µs [28]

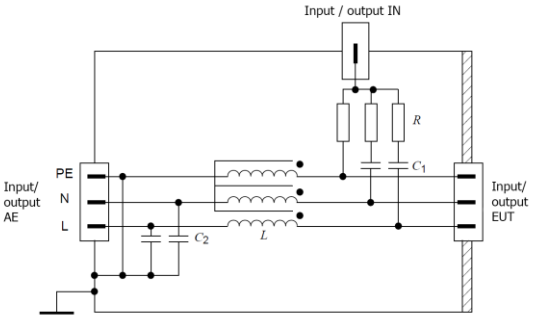
6.5 Immunity to conducted disturbances, induced by radio-frequency fields

Test method: ČSN EN 61000-4-6

Test setup: The DUT is placed on the 10 cm high insulating support on the table with RGP. The disturbing signal from generator is connected to the tested interface via suitable coupling. The frequency range of the test is usually from 150 kHz – 80 MHz with 1% frequency step and minimally 0.5 s testing time.

The coupling method for the disturbing signal::

- CDN´s:
  - type M for power supply line,
  - type S for shielded cable,
  - type AF for unshielded and unbalanced signal line,
  - type T for unshielded balanced signal line,



CDN-M3, C_1 (typical) = 10 nF, C_2 (typical) = 47 nF, R = 300 Ω, $L \geq 280$ µH at 150 kHz.
CDN-M2, C_1 (typical) = 10 nF, C_2 (typical) = 47 nF, R = 200 Ω, $L \geq 280$ µH at 150 kHz.
CDN-M1, C_1 (typical) = 22 nF, C_2 (typical) = 47 nF, R = 100 Ω, $L \geq 280$ µH at 150 kHz.

Fig. 47: Example of connection of CDN M type [29]

- EM clamp, if the CDN is not possible to use.

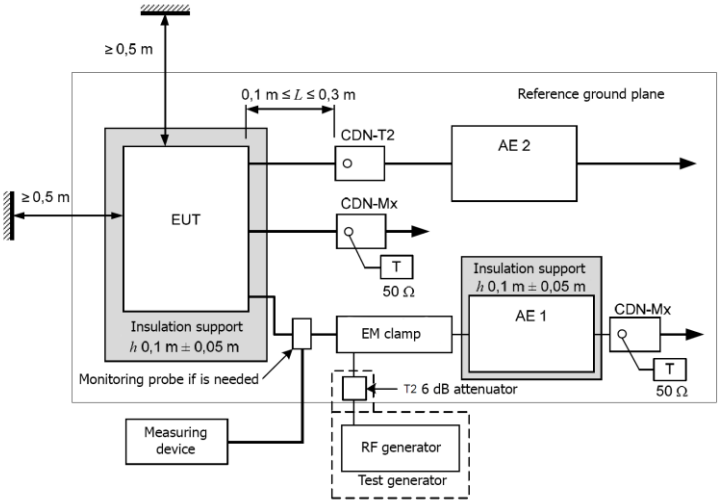


Fig. 48: Test setup with CDN and EM clamp [29]

Test levels:

Level	Unmodulated signal level	
	V_0 (V)	V_0 (dBµV)
1	1	120
2	3	129,5
3	10	140
x *1)	Special	Special
*1) test level x can be any other value lower, higher or between other levels.		

Waveform of the disturbing signal: same like as ČSN EN 61000-4-3

6.6 Power frequency magnetic field immunity test

Test method: ČSN EN 61000-4-8

Test setup: The DUT is placed in the center of the loop antenna through which the current (with mains frequency) from the test generator passes. The minimum testing time is 1 min for each of 3 testing axes.

The coupling method for the disturbing signal: Magnetic field in open space area generated by loop antenna:

- 1 x 1 m or
- 1 x 2.6 m.

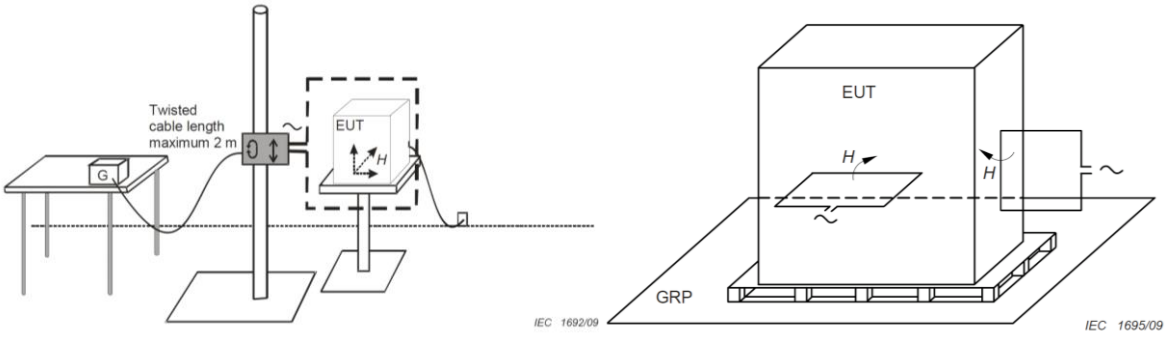


Fig. 49: Example of the test and proximity method [30]

Test levels:

Level	H-field level (A/m)	
	Continous	Pulsed (1 – 3 s)
1	1	NA
2	3	NA
3	10	NA
4	30	300
5	100	1000
x [*1)]	Special	
[*1)] test level x can be any other value lower, higher or between other levels.		

Waveform of the disturbing signal: The current of power line frequency (50 Hz) flows through the antenna. The H-filed in the center of the antenna is equivalent to the current (approx. 1,15x higher then intensity for 1 x 1 m antenna and approx. 1,51x for 1 x 2.6 m antenna).

6.7 Voltage dips, short interruptions and voltage variations immunity tests

Test method: ČSN EN 61000-4-11

Test setup: Short-term voltage dips and interruptions were applied to the AC power supply of the subject under test.

The coupling method for the disturbing signal: Direct coupling (two power supplies – one with full voltage, second with reduced/zero voltage). The switching time equals to 1 – 5 µs.

NOTE: Slow voltage dips: fast change to 70% V – one period time with 70% V – increasing to full voltage for 500 ms.

Test levels:

Class *2)	Voltage dips, 50 Hz				
1	According to the DUT requirement				
2	0%, 10 ms	0%, 20 ms	70%, 500 ms		
3	0%, 10 ms	0%, 20 ms	40%, 200 ms	70% 500 ms	80%, 5 s
x *1)	x	x	x	x	x
	short interruptions, 50 Hz				
1	According to the DUT requirement				
2	0%, 5 s				
3	0%, 5 s				
x *1)	x				
*1) according to product standarddle výrobkové normy *2) according to IEC 61000-2-4					

Waveform of the disturbing signal:

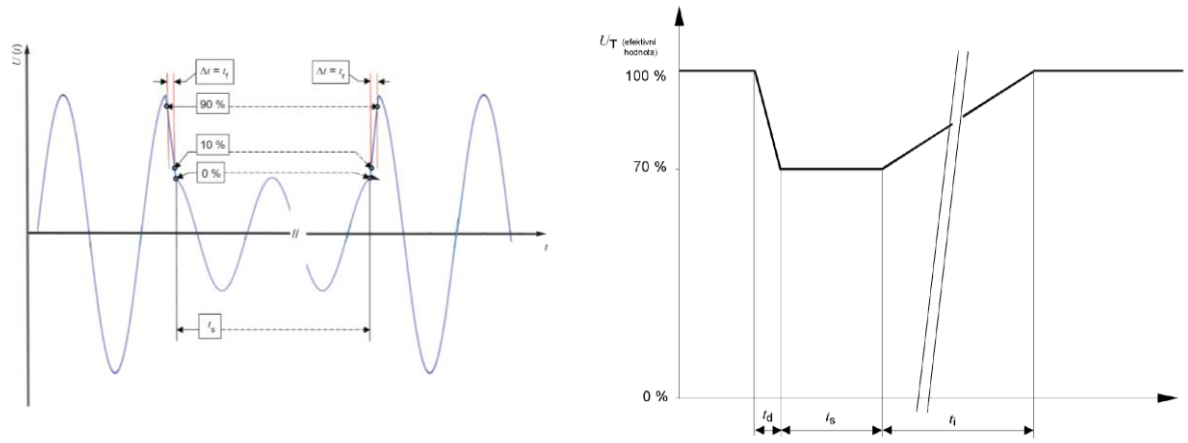


Fig. 50: Example of fast / slow voltage dips wavweform [31]

NOTE: EMC testing in EMC lab
For a smooth measurement in the EMC laboratory, a precise specification of the device and its interface is required (for the laboratory already during the demand assessment).

7 Pre-compliance EMC measurements

The emission measurement and immunity testing of the DUT must be performed according the standards – the standards specify measurements setups, levels, etc. The standards family CISPR 16 specifies requirements for emission measurements; the standards family ČSN EN 61000-4-X specifies requirements tor immunity testing.

Pre-compliance measurement could be divided to two groups:

- EMC measurements of the device during its development, when the already implemented functional units of the newly designed equipment are measured or tested by standard procedures (eg in an accredited laboratory), or
- EMC measurements of the whole device using non-standard self-help procedures, where the emphasis is on saving money.

7.1 Pre-compliance susceptibility testing

In terms of performance, pre-certification susceptibility testing is very limited, for several reasons:

- If the device is not complete (in terms of functionality), the results may not correspond to the tests with the final device (even if it is tested by standardized test procedures).
- The disturbance generators are necessary to use for susceptibility testing – there is no easy way how replace them.
- The anechoic chamber is necessary for radiated, radio-frequency, electromagnetic field immunity test.

Some tests could be performed using generators (especially for transient tests), but these tests are close to certified tests (if the test conditions and configurations are met to the standard).

7.2 Pre-compliance emission measurements

There exist some alternative methods for compliance measurement in the terms of relative accurate for low budget – if some condition are met. One way is to use spectrum analyser – there could be possibility to expand it by EMI detectors and by EMI RBW.

NOTE: Main difference between EMI receiver and spectrum analyzer

EMI receiver	Spectrum analyzer
	

EMI receiver	Spectrum analyzer
RBW	
Defined for -6 dB	Defined for -3 dB (option for EMI RBW -6 dB)
Tuning method	
Dwell time (step by step) (Δfmax = RBW/2)	Sweep time (time fmax – fmin)
Frequency resolution	
Δfmax = RBW/2	(fmax-fmin)/(measuring points-1)
Detectors	
QP + AVG + RMS + PK (CISPR16)	PK + AVG (not CISPR) + RMS (option QP + AVG)
Detector responses to impulse	
Defined	???
Input circuits	
Preselector*, attenuator, preamp	Attenuator, preamp

* preselector is a set of bandpass filters which limits the measuring frequency range. In this case, no signals from other bands are at the mixer input – these signals influence the results (compression of input signals).

Example: Conducted emission measurement in the frequency range 150 kHz – 30 MHz, QP + AVG detectors.

Solution:

1. Frequency step for EMI receiver – for band B is defined RBW = 9 kHz, ie. maximum step equlas to $\Delta f = \frac{1}{2} RBW = \frac{9\ kHz}{2} = 4.5\ kHz$. Number of measuring point is: $\frac{(fmax-fmin)}{\Delta f} = \frac{(30\ MHz-150\ kHz)}{4{,}5\ kHz} = 6634$ measuring points. The measuring time for direct measurement with QP + AVG detectors is 6634 s, approx. 111 minutes. But is is only 0,5 ms x 6634 = 3,4 s for PK detector – it is the shortest theoretical measuring time.
2. The minimal sweep time of spectrum analyser is 2,985 s (see table X). Number of measuring poins depends of the spectrum analyser type – there is use usually hunderds of point, for example 601 points. I.e.the step between two points equals to $\Delta f = \frac{(fmax-fmin)}{601-1} \approx 50\ kHz$. It causes mistake in frequency measurement, also In level measurement. There is necessary to divided the whole frequency range to subranges with correct frequency step (max. 4,5 kHz):
   subrange 1: 150 kHz – 2850 kHz (150 kHz + (600 x 4,5 kHz)),
   subrange 2: 2850kHz – 5550 kHz (2845,5 kHz +(600 x 4,5 kHz)),
   subrange 3: 5550 kHz - …
   …
   subrange *n*: … - 30 MHz.
   Now the measured spectrum corresponds with EMI receiver spectrum – for PK detector measurement…

7.2.1 Pre-compliance measurement of conducted emission

Some type of transducer is necessary for conducted emission measurement – usually AMN is used. Also the correct seting of measuring equipment is crucial for corret measurement – especially setting of frequency range, attenuation of transducer and cables, etc. The manufacturers of measuring equipment have usually some type of evaluation software (cost extra money…), it usually includes comparison of measured values with limit and final measurement with QPK detector (if the spectrum analyser has QPK detector). Without the evaluation software can not be performed max-hold measurement for all phases, there is necessary performed measurement for each phase separately (see Fig. 51). The evaluation must be performed for each phase – if one of measurement does not met with limit, than the DUT does not met with the standard. Spectrum analyzer allows to shown the limit line with the measured trace (PK detector).

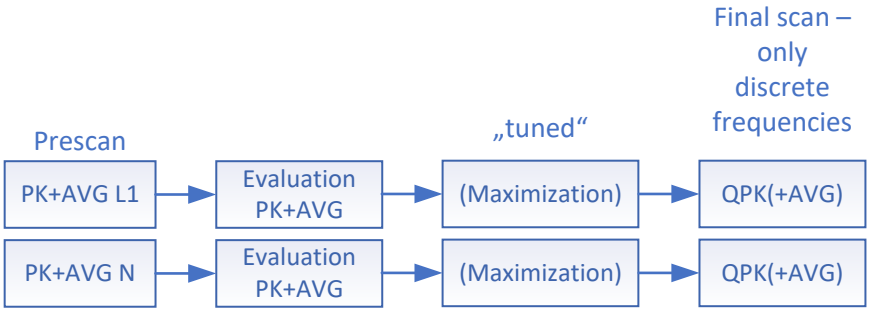


Fig. 51: Example of conducted emission measurement without evaluation SW, also spectrum analyzer measurement with evaluation SW

7.2.2 Pre-compliance measurement of radiated emission

Some types of measurement chambers are recommended for radiated emission measurement (far field measurement, from 3 m measuring distance almost always met) – SAC or FAR (especially for attenuation of background noise). The background noise level in open area test site (or in-situ measurement) usually exceeds the limit lines for defined environment (the initial condition for background noise level = limit – 6 dB is not met).

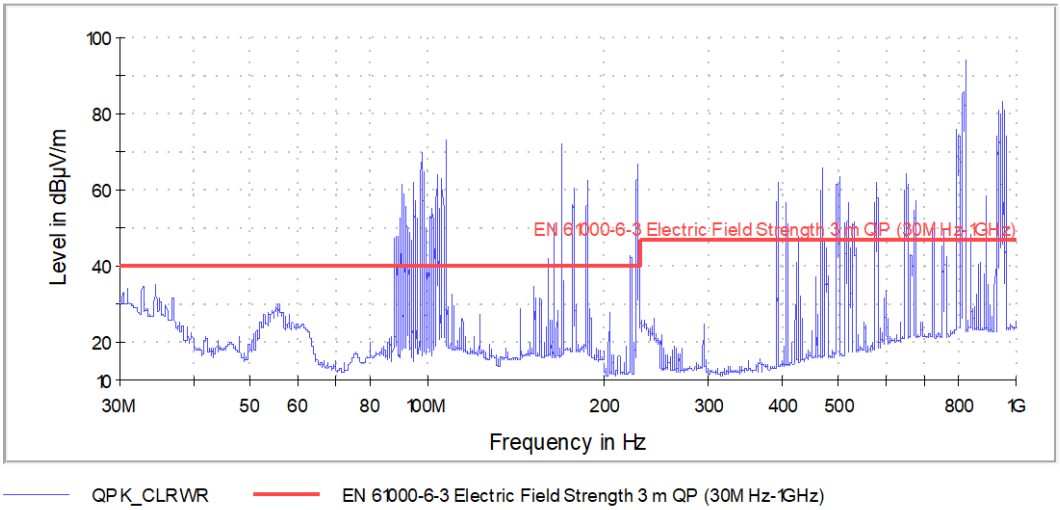


Fig. 52: Example of the background noise in open area test site, 30 – 1000 MHz

The radiated emission measurement in the open area test site is not recommended to perform due to high background noise level – it represents difficult evaluation – there is necessary to perform also background measurements before and after the DUT measurement.

7.2.3 Localization of the interference source

The standardized measuring setup does not detect the source of the interference, only detect its consequences – whether it is conducted emissions (at the supply or signal terminals) or radiated emissions (measured in the far field). For this reason, it is necessary to determine how to locate the source of interference. After that, it is possible to eliminate the interference (suppress it to the defined level).

Measurement with near field probes is possible perform really close to the DUT (for example near PCB). T the sensitivity of near field probe is not good – the relatively large probes are used for the first localization, the smaller probe is used for better localization. There are probes for measurement H or E-field. The frequency range can be approx. 100 kHz – tens of GHz (does not apply to individual probe – there the frequency range is around two decades).



Fig. 53: Near field probes (web Langer)

Measurement using high impedance probe that is connected to the spectrum analyser – there is possible measure directly to the lines with potencial (of DC voltage). The frequency range can be around 100 kHz – 3 GHz, the limitation is mostly related to the maximum input voltage – usually is around ± 50 V.



Fig. 54: High impedance probe (web Keysight)

Oscilloscope measurement – the measurement is possible at relative low frequencies - it depends on the scope parameters, especially at his bandwidth.

Generally, these measurement setups are called pre-compliance EMC measurements

8 Vocabulary

Selection of some EMC terms defined in the standard ČSN IEC 50 (161) - International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility.

- **Electromagnetic compatibility; EMC** – the ability of an equipment or system to function satisfactorily in its electromagnetic environtmentwithout introducing aintolerable electromagnetic disturbances to anything in that environment (161-01-07).
- **Reference-ground plane; RGP** – flat conductive surface that is at the same electric potential as reference ground, which is used as a common reference, and ehich contributes to a reproducible parasitic capacitance with the surroundings of the equipment under test (EUT) (/A5; 161-04-36).
- **High frequency** – frequency above 9 kHz (/A4 ; 161-1-25)
- **Low freqency** – frequency to and including 9 kHz (/A4 ; 161-1-26)
- **Port** – particular interface of an equipment which couples this equipment with the external electromagnetic environment (161-01-01) and trough which the equipment is influenced by this environment (/A4 ; 161-01-27).
- **Electromagnetic environment** – the totality of electromagnetic phenomena existing at a given location.
- **Interfering signal** – a signal that impairs the reception of a wanted signal.
- **(electromagnetic) compatibility level** – the specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operated in particular condition.
- **Electromagnetic disturbance** – any electromagnetic phenomenon which may degrade the performance of a device, quipment or system ar adwersely affect living or inert matter. NOTE: An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation mediun itself (/A8; 161-01-05).
- **Electromagnetic interference; EMI** – degradation of the performance of an equipment, transmission channel or system csused by an electromagnetic disturbance (/A8; 161-01-06).
- **Immunity** (to a disturbance) – the ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.
- **(Electromagnetic) susceptibility** – the inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance. NOTE: Susceptibility is a lack of immunity.
- **Emission level (of a disturbing source)** – the level of a given electromagnetic disturbance emmited from a particular device, equipment or system, measured in a specific way.
- **Emission limit (from a disturbing source)** – the specified maximum emission level of a source of electromagnetic disturbance.
- **Electromagnetic emission** – phenomenom by which electromagnetic energy emanates from a source (/A9; 161-01-08)
- **Conducted disturbance** – electromagnetic disturbance for which the energy is transferred via one or more conductors (/A1 ; 161-03-27)
- **Radiated disturbance** – electromagnetic disturbance for which the energy is trnaferred through space in the form of electromagnetic waves (/A4 ; 161-03-28).

- **(electromagnetic) disturbance level** – the level of an electromagnetic disturbance existing at a given location, which results from all contributing disturbance sources (/A1; 161-03-29.
- **Limit of disturbance** – the maximum permissible electromagnetic disturbance level, as measured in a specifield way.
- **Limit of interference** – maximum permissible degradation of the performance of a device, equipment or system due to an electromagnetic disturbance.
- **Immunity level** – the maximum level of a given electromagnetic disturbance incident an a particular device, equipment or system for which it remains capable of operating at a arequired deree of performance.

References

[1] Zákon č. 90/2016 Sb., o posuzování shody stanovených výrobků při jejich dodávání na trh, částka č. 36/2016 Sb., aktuální znění 12.6.2018

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