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Študija elektromagnetnih interferenc med električnimi napravami/sistemi v frekvenčnem območju pod 150 kHz - 2. izdaja

Study Report on Electromagnetic Interference between Electrical Equipment/Systems in the Frequency Range Below 150 kHz Ed. 2

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Study Report on Electromagnetic Interference between Electrical Equipment/Systems in the Frequency Range Below 150 kHz

Rapport d'étude sur les perturbations électromagnétiques entre les équipements / systèmes électriques entre eux dans la plage des fréquences inférieure à 150 kHZ

Studienbericht über elektromagnetische Interferenz zwischen elektrische Betriebsmittel/Systeme im Frequenzbereich unter 150 kHz

This Technical Report was approved by CENELEC on 2015-11-02.

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European Committee for Electrotechnical Standardization
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European foreword

This document (CLC/TR 50627:2015) has been prepared by CLC/SC 205A "Mains communicating systems".

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This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association.

This Technical Report provides useful information for standards related to the following European Mandate(s): M/441, M/490.

This Technical Report is based on the Study Report “Electromagnetic Interference between Electrical Equipment / Systems in the Frequency Range below 150 kHz” of SC 205A (SC 205A/Sec0339/R:April 2013) (second edition) [1b], with some update according to the developments that have taken place since.

Introduction

In April 2010, CLC/SC 205A[1)] published their first Study Report on “Electromagnetic Interference between Electrical Equipment in the Frequency Range below 150 kHz” [1a]. Related studies had been made and information gathered due to first cases of EM interference, with Touch-dimmer lamps (TDLs) as an EMI victim, an inverter as an EMI source, and automated meter reading systems using powerline communication (AMR-PLC) figuring as EMI victims as well as sources.

Following this first CLC/SC 205A Study Report, its second edition [1b] and, based on it, this Technical Report aims at:

a) highlighting the broad relevance of recognized electromagnetic interference for safeguarding EMC also in the frequency range 2 kHz – 150 kHz;

b) extending knowledge about:

1) EMI cases having been observed between electrical equipment in the frequency range 2 kHz to 150 kHz, with an emphasis on interference between:

i) electrical equipment and its non-intentional emissions (NIE);

ii) mains communicating systems (MCS) using (powerline communication) PLC technology with intentional signal injection for the transmission of information over the electricity supply network;

2) different mechanisms causing interference to electrical equipment due to non-intentional or intentional voltage/current components in the considered frequency range;

as a basis for evaluating the need for closing the recognized gap in standardization as highlighted in the first edition, and considering the recent developments; that:

c) without evaluating certain types of electrical equipment concerning applied technology or priority;

d) and with regard to:

1) problems having occurred with operational equipment of distribution network operators (DNOs), in particular related to smart metering and smart grids control and monitoring equipment;

2) complaints by network users to deliverers and subsequently by deliverers to DNOs or by network users directly to their DNO, about degradation or loss of function of certain electrical equipment;

3) in both cases network users as well as deliverers are primarily annoyed by the troubles they are experiencing with electrical equipment they have traded or bought, trusting in its interference-free operability, which they expect due to the CE mark.

This TR is based on:

e) reports on EMI cases and, following related complaints, investigations performed by an accredited test house, universities, DNOs, manufacturers and consultants;

f) measurements performed by an accredited test house, universities, DNOs, manufacturers and consultants. In both cases to extend knowledge of emissions from different equipment in the considered frequency range, in case of the occurrence of EMI:

1) to identify the actual interference source;

2) to clarify the interference mechanism;

3) to evaluate mitigation measures;

g) the present standardization situation and its actual development.

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1) CLC/SC 205A Mains communicating systems.

1 Scope

This Technical Report is based on two Study Reports of CLC/SC 205A, having been worked out by their Task Force EMI [1a][1b] and provides the results and findings of these documents. It was created with the help and input from a broad range of involved stakeholders: network operators, equipment manufacturers, universities, accredited test houses and consultants.

Beside the actual standardization situation it reflects the current emission situation found in supply networks and installations and describes electromagnetic interference (EMI) cases from twelve countries; investigation and analysis of the latter show a wide range of different types of electrical devices to be considered as a source or a victim of related EMI.

This Technical Report highlights the occurrence of high levels of non-intentional emissions (NIE) in the considered frequency range, including values up to and exceeding the standardized limits for intentional signals from mains communicating systems (MCS), which also implies a high potential to cause EMI to other electrical equipment. On the other hand, several types of equipment show susceptibility to related emissions, being insufficiently immune.

The Technical Report addresses the following issues:

- a number of different types of electrical equipment are generating such emissions and/or are susceptible, to such, thus representing EMI potential, as a source or a victim of such EMI;
- the interaction of electrical equipment in a certain supply area respectively installation, with its complex and volatile impedance character, as having an additional EMI potential; that besides NIE from general electrical equipment and signals from MCS and technically being quite different from emissions;
- the fact that besides the conducted interference also radiated interference from NIE or signals from MCS, through the magnetic H-field following to related currents on the mains, is to be considered, what is of some importance also for the interference-free operation of broadcast time-signal systems or electronic circuits controlled by such;
- the ageing of electronic components in electric equipment, which causes increased emissions and EMI to other electrical equipment as a result of not showing the same EMC characteristics as before being placed on the market, therefore no longer being able to conform with EMC requirements;
- the additional aspect of differential mode operation, which should be considered for related immunity and testing specifications.

These findings confirm that EMI in this frequency range is not limited to single types of equipment like inverters or MCS; instead a more general electromagnetic compatibility (EMC) problem concerning a larger spectrum of electrical equipment is identified.

Although a case-by-case mitigation of related EMI cases might be seen as appropriate, the increasing application of technologies and systems with related EMI potential requires a more general solution, through standardization, taking a balanced viewpoint of EMC and economics into account. With regard to the actual standardization situation, a review of the actual EMC and Product standards based on the reported results seems to be advisable.

After initiating the work in CLC/SC 205A, the now ongoing work in IEC SC 77A, as well as the publication of a related Technical Report on testing electricity meters [2] by CLC/TC 13 and of the new Immunity testing standard EN 61000-4-19 [99], appear as right steps into the right direction but needing further, extended efforts.

As stated on European as well as on international EMC standardization level, the availability of compatibility levels for the considered frequency range appears as a key-requirement for future considerations on setting related emission limits and immunity requirements in various standards. A fundamental basis for the co-existence of intentional signals from MCS and NIE needs to be found.

2 General

When talking about EMI in the frequency range 2 kHz to 150 kHz it is appropriate to highlight the development of electricity application respectively the use of the electricity supply network during the past decades, which is characteristic for the today's given situation; this development has led to:

a) a thorough increase of comfort in the application of electrical energy, including the realization of some energy saving effects, in particular through the application of power electronics, and with that, a somehow changed use of the electricity supply network;

b) the deployment of smart metering, in Europe using in the large majority of cases PLC for data transmission, with at present:

   1) more than 50 m PLC endpoints in Europe, from some ten thousand AMR-PLC in Austria to 36 m in Italy;
   2) an expected amount of such smart meters of around 85 m by 2013, 155 m smart meters by the end of 2016 and 250 m smart meters by the end of 2020 [3], [4];
   3) an intermediate status of related projects from beginning of rollout (Spain) to 99 % (Italy);

c) a further extended use of the supply network for operational electricity suppliers' information transmission purposes, in particular with regard to the intended deployment of smart metering and smart grid solutions [5], [6], comprising the installation of about 200 m smart meters in the next 5 years – 7 years with a cumulative investment of up to 40 bn € for smart meters and about 280 bn € for other measures to realize smart grids [7];

that technically accompanied by the superposition of additional voltage components on the practically pure sine wave of the mains voltage.

As a consequence, dependant on the different types of connected equipment/systems at a certain time,

- apparatus/systems using electric energy;
- distributed generation units (DGU) with its ancillary systems;
- MCS;

the original sine wave of the supply develops towards a somehow different shape, which shall be considered for its possibly disturbing effect on the operation of electrical equipment; with regard to the different types of such emissions, figuring as disturbances causing EMI, i.e.:

- intentional emissions, i.e. signals;
- non-intentional emissions or
- a combination of both ones;

and following to the cumulative effect of the additional voltage components, for ensuring EMC, the need for appropriate setting of compatibility levels as well as of emission limits and immunity requirements (see also [64]) is given.

Apart from the technical aspects, but connected with it to a certain extent, several EU Directives and Standardization Mandates (see e.g. [5] – [12]) figure as a background for these changes in the use of electricity supply networks. This has also been expressed by the Communication of the Commission on Smart Cities and Communities – European Innovation Partnership [13], which aims at catalyzing progress in areas where energy production, distribution and use, mobility and transport and information and communication technologies (ICT) are intimately interlinked and offer new interdisciplinary opportunities to improve services; that mainly with regard to the global energy situation which, exceeding the primary and basic goal of supplying electrical energy by far, requires measures for ensuring a future-proof energy supply including:

- the efficient use of electrical energy in general;
- increased use of renewable energies, with its ancillary systems for coupling to the supply network, for decentralized generation;
- improved information to the network user about energy consumption together with actual tariffs as well as extended information for the energy supplier about the actual operational and quality status of his network, by extensive information exchange from and to smart meters;
- considerations for the realization of smart grids;
- the realization of appropriate IT infrastructure, as the basis for the aforementioned projects.

3 The frequency range from 2 kHz to 150 kHz

3.1 Challenges in terms of EMI

Regarding EMC (see definition in the EMCD[2)] [14] and the IEV[3)] [15]), on principle:

- unintentional emissions from non-mains-communicating equipment / systems (NCE) or communication equipment, or
- communication signals, both figuring as “emissions” and having some potential for causing EMI, or
- a combination of both ones

shall be considered, according to the classical viewpoint in terms of voltage/current levels, that together with:

- the cumulative effect of voltage components from all emitting equipment connected to a supply network;
- different proliferation of different types of electric equipment and its different times and durations of operation;
- utilization of the frequency range below 150 kHz (see also 3.2).

To ensure EMC and to meet the Essential Requirements (ERs) of the EMCD, a balanced co-existence of appropriately set emission limits, appropriately realized equipment immunity to emissions (non-intentional and signals) and to the supply network characteristics is necessary (see also [16]).

Besides the numerical values of voltage/current levels, at least for the frequency range 2 kHz – 150 kHz, the voltage/current shape is a character which has some impact on the sensitivity of electrical equipment to EM disturbances and should therefore be considered when dealing with EMC requirements for this frequency range in general and with related immunity in particular (see 3.3).

Depending on the levels of such emissions as well as on the voltage shapes of these emissions, the resulting modification of the supply voltage’s sine wave through NCE or communication equipment can be followed by:

- degradation of function, maloperation or damage of network users’ or energy suppliers’ equipment;
- degradation of performance of MCS, e.g. AMR-PLC;
- display of wrong meter register values.

Table 1 gives an overview of a somehow more detailed grouping of EMI effects (see also [17] – [19]).

Table 1 — Main groups of EMI effects

(Non-intentional) Emissions from network users’ equipment at or close to frequencies used for MCS interfere with intentional MCS signals, leading to disturbance or loss of MCS communication
Multiples of (non-intentional) emissions from network users’ equipment, being close to frequencies applied for MCS may cause interference with the MCS resulting in failed communication
Distortion of the supply voltage due to discontinuous (non-intentional) currents/ voltages from network users’ equipment or signal voltages from MCS may lead to degraded performance or maloperation of network users’ equipment
Network users’ equipment representing a low-impedance path at frequencies used for MCS lead to an attenuation of the intentional MCS signal which might disturb or interrupt communication (“shunting effect”)
(Non-intentional) emissions from network users’ equipment or (intentional) MCS signal voltages may result in somehow higher currents, leading to overheating and accelerated ageing of components in network users’ equipment

2) Electromagnetic Compatibility Directive.
3) International Electrotechnical Vocabulary.

For the frequency range 2 kHz – 150 kHz, at first sight, it appeared that mainly touch-dimmer-lamps (TDLs), inverters and AMR-PLC were involved in related interference [1a]. Anyhow, already in Study Report I,

- EMI cases have been mentioned with other types of equipment having been involved as a source or victim;
- the assumption has been expressed, that somehow more types of equipment could be needed to be considered as EMI sources or victims.

Summarizing information having been gathered from 12 countries (AT, BE, DE, FI, FR, GB, HU, IT, JP, NL, NO, SE)[4)] about related measurements and investigations on EMI cases and measurement results being described in Clauses 4 and 5, Tables 2 and 3 give an overview of types of equipment showing high level emissions in the related frequency band or having already been recognized as a source or victim of such EMI (see also [1a], [20 – 23]).

Table 2 — Equipment figuring as a source of EMI, Examples

Inverters (e.g. in PV installations) and variable speed drives (VSD), (e.g. in elevator drives, ski lift drives, heating system circulation pumps, ventilation systems, household equipment)
Switch-mode power supplies (e.g. in lighting equipment, PCs, consumer electronic/home entertainment equipment (e.g. TV, DVD), ICT equipment, uninterruptible power supplies (UPS), charging devices)
Lighting equipment (e.g. fluorescent lamps, compact lamps, LEDs)
Household equipment (e.g. induction cookers, washing machines, electric shavers)
Portable mains operated tools
AMR-PLC

Table 3 — Equipment figuring as an EMI victim, Examples

AMR-PLC
Solid state meters
Electronic control (e.g. touch-controlled equipment like Touch Dimmer lamps (TDL), alarm systems, traffic control systems, traffic lights, in heating systems, street lighting, in urinals, for doors, in kitchen appliances (e.g. steam irons, coffee machines, ceramic hobs)
Communication systems (e. g. Ethernet-system, ISDN-, ADSL-modems, IP network branch exchange, routers, LAN)
Telephone systems including inductive train radio systems
Earth leakage circuit breakers (ELB)
Contactless magnetic card readers, credit card terminals
Notebooks (cursor position)
Broadcast standard time-signal systems (e.g. DCF77, Japanese system)
Road vehicle smart keys
TV and radio receivers
Mobile radio
Amateur radio

Tables 2 and 3 may need further amendments in future, following further investigations.

Table 4 provides information about different effects of EMI to certain equipment in the considered frequency range.

4) Austria, Belgium, Finland, France, Germany, Great Britain, Hungary, Italy, Japan, The Netherlands, Norway, Sweden.

Table 4 — Effects of EMI to equipment in the frequency range 2 kHz– 150 kHz, Examples

TDLs	Unintentional switching (between light steps, OFF, also ON)
Street lighting	Unintentional switch-on and –off
Traffic lights	Malfunction
Traffic control system for public transportation buses	Malfunction
Solid state meter	Displaying wrong meter register values
MCS	Temporary or quasi-permanent loss of data transmission function
Heat control with time basis through DCF77 signal	Malfunction
Heating systems	Incorrect alarms due to sensor faults
Contactless magnetic card reader	Malfunction of reading function
ADSL modem	Loss of link, CRC error
Routers	Loss of synchronization (40, 50 and 70 kHz) to the network
Notebooks	Disturbed cursor position (37 kHz)
Inductive Train Radio System	Audible noise
Ceramic hobs	Incorrect relay switching
Coffee cooker	Incorrect control lamp function
Steam irons	Insufficient heat, water loss, incorrect control lamp blinking
Washing machines	Self-restart (some hours) after end of operation phase
Automatic urinal water control	switching to permanent operation
Broadcast standard time-signal systems	Electronic clocks: being fast (gaining up to 15 mins per day), Malfunction of control circuits fed by the time-signal
TV and radio receiver	Audible noise (up to 20 kHz)
Amateur radio	Disturbed reception of distant transmitters

With this overview of potential EMI sources/victims as well as EMI effects together with the measurement and investigation results in Clauses 4 and 5 of this Technical Report it may be taken as a fact, that the EMI potential in the frequency range below 150 kHz, already mentioned in Recommendation Com-1 of the Report “Standards for Smart Grids” published by the CEN/CENELEC/ETSI SG-CG in 2011 [24] (see also [25]), is not restricted to PLC devices and domestic appliances but shall be seen as having a quite larger dimension. This will need to be resolved by creative approaches taking into account the installed base, i.e. products on the market, and future technology development.

3.2 Frequency utilization

When considering the utilization of the frequency range below 150 kHz for different purposes, there is to be distinguished between:

a) conducted voltage/current components representing:

1) non-intentional emissions (NIE), stemming from:

i) NCE as a consequence of the applied technology and being a more or less unavoidable waste product of its application of electrical energy;

ii) from MCS as spurious emissions from such, i.e. unwanted signals, both types of emissions to be considered as disturbances in the sense of the IEV [15] definition of “electromagnetic disturbances” (see also Recommendation 13. in Clause 9);

2) voltage/current components

i) stemming from NIE (see above) or MCS signals (see below),

ii) being induced from wires in an installation via the magnetic H-field to another installation or an electronic circuit

3) communication signals from MCS, being intentionally impressed on the 50-Hz-supply voltage for the purpose of transmitting information, e.g. for smart metering/smart grid systems in the

public supply area or for network users' purposes within their installation, e.g. for data transmission within their premises or for home automation.

Figure 1 shows the frequency ranges designated to applications using (narrow-band) MCS:

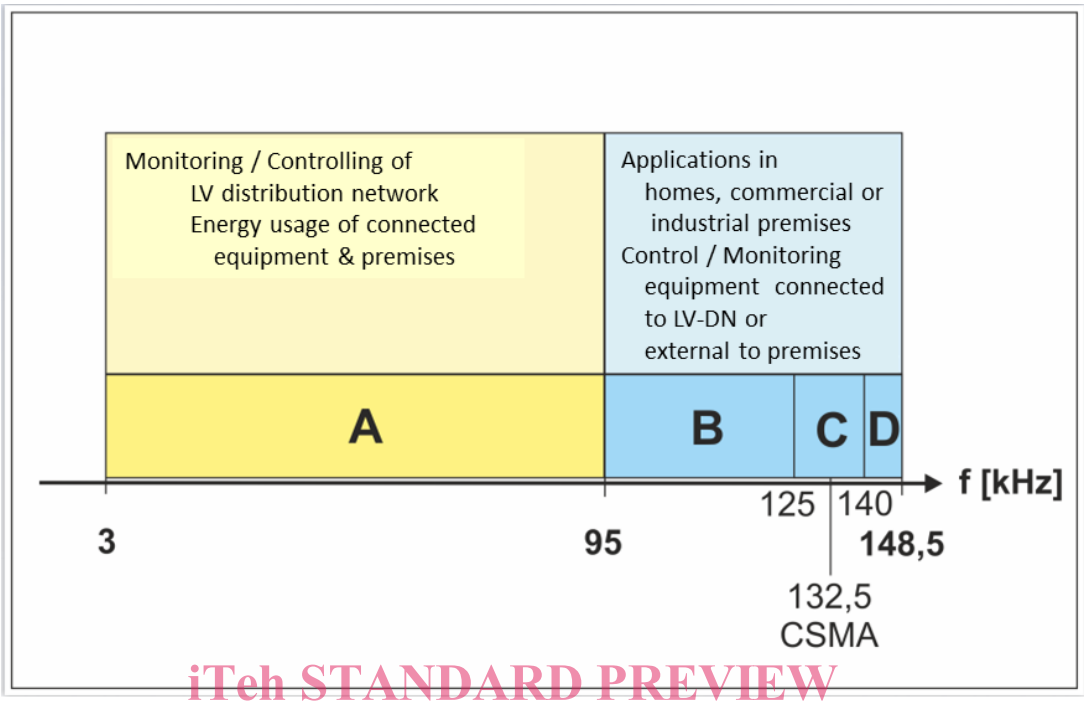

Figure 1 — Frequency band designations according to EN 50065-1 [26]

All the aforementioned voltage/current components have some potential for causing EMI, for which also a combination of the different types shall be considered, that together with:

- the cumulative effect of voltage components from all emitting equipment connected to a supply network;
- different proliferation of different sorts of electric equipment and its different durations of operation.

The aforementioned cumulative effect represents some criterion for dealing with both types of emissions, as:

- NIE are generated from a lot of different equipment operated in a certain supply area and there-fore contributing to a certain cumulative load of such emissions at a certain instant, which varies over time;
- MCS signals, in any case in CENELEC-band A (Figure 1), are normally present in a certain supply area only from *one* MCS, therefore not experiencing any accumulation.

That leads also to the recognition, that – e.g. concerning setting immunity requirements – signals need to be treated different from NIE.

b) radiated magnetic fields stemming from

1) non-intentional currents due to the operation of electronic circuits, as explained above;

2) signal currents from MCS, intentionally impressed on the supply voltage as explained above.

Also these magnetic fields, resulting from non-intentional or signal currents, have some EMI potential, by causing conducted voltages getting induced to installations or electronic circuits (see 5.3.1, List Entry a)).

c) radio applications for services, like broadcast time-signal services.

Concerning the first-mentioned group a):

- contrary to the frequency range up to 2 kHz, where normative specifications exist for harmonics [27] and voltage fluctuations [28] in a LV supply network and up to 3 kHz, where emission levels for intentional signalling from ripple control are standardized (Meister curve) by EN 61000-2-2 [29];
- besides the subject areas of:
    i) lighting equipment and induction cookers [30], [31];
    ii) the Basic standard EN 61000-4-16 [32] specifying test conditions for electric and electronic equipment concerning immunity to conducted asymmetrical disturbances in the frequency range 0 kHz – 150 kHz;
    iii) narrow-band MCS technology, where emission limits and immunity requirements have been standardized for the frequency range 3 kHz – 148,5 kHz, by the EN 50065 series [26], [33] – [35] on from 2001 (see also IEC 61000-3-8 [36] and IEC 61334-3-1 [37] concerning frequency bands and output levels and [38] – [45] for additional normative specifications (filters, couplers, equipment impedance).

this frequency range 2 kHz – 150 kHz, up until now, has not been considered for setting limits for NIE (see 6.1). Recently, some developing situation is given in the field of power electronics, where first proposals for recommending emission values for Active Infeed Converters (AICs) have been approved in IEC/TS 62578 ([46] (see 6.1)).

Concerning radiated magnetic fields no standardized limits exist for this frequency range; that likewise as recently no technical specifications are available for evaluating an EMI situation with EMI to broadcast time-signal systems, although to be seen as protected, in any case in terms of radio interference (see 5.3.1).

With regard to the recognized co-existence problems between equipment generating NIE and MCS in the frequency range 2 kHz – 150 kHz, it is of some interest whether:

- concerning EMC, standards need to consider existing products/technologies on the market
- the intended operation of MCS were to be seen as being protected by the EMCD.

(See also Clause 6.)

The primary status of a standard shall be considered as voluntary, which could be changed if a standard becomes part of a contract

Concerning the EMCD, related discussions resulted in the recognition, that with the inclusion of telecommunication systems/networks in its scope, the EMCD and its ERs are protecting the intended operation also of MCS.

3.3 The impact of voltage / current shapes

From Study Report I [1a] it is known, that besides the numerical values of voltage/current levels, at least for the frequency range 2 kHz – 150 kHz, also the voltage/current shape is a character which has some impact on the sensitivity of electrical equipment to EM disturbances -- what should therefore be considered when dealing with EMC requirements for this frequency range in general and with related immunity in particular.

When having reported about the first investigation results, having been achieved during measurements concerning EMI from AMR-PLC to TDLs, it was shown, that, for the considered frequency range, interference is also a matter of rise (or fall) time of the amplitude/envelope of voltage/current components.

For example, Figure 2 shows the rise of sine wave signal components in the supply voltage with a frequency of 55 kHz respectively 90 kHz, by which a TDL has been switched on. The instant of time of switch-on of the TDL can be recognized through the start of network disturbances from the TDL's triac-controller (see sequences of narrow spikes outside the envelope of the test signal).

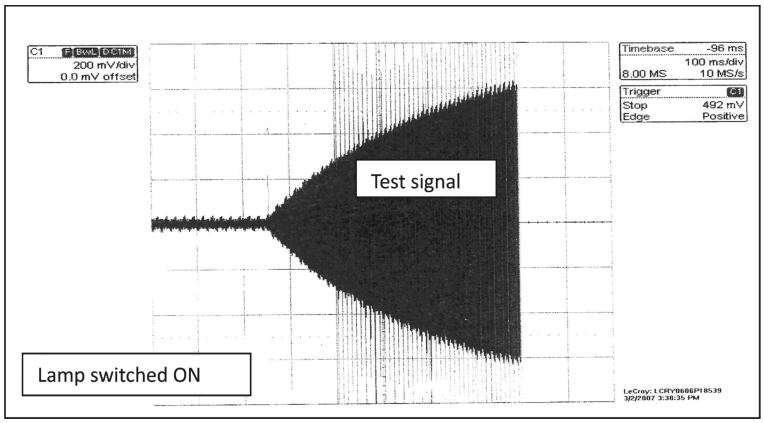

Figure 2 — Sine wave components in the supply voltage, ((test signal) frequency: 90 kHz), leading to a switch-on of a TDL

Additional investigations have been made by an accredited test house [47], with a (modulated) test voltage according to Figure 3 applied to a TDL.