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Guidance on the selection and implementation of performance requirements for utility meters containing additional functionalities

OIML E 6 Edition 2011 (E)

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

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The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States. The main categories of OIML publications are:

- **International Recommendations (OIML R)**, which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity. OIML Member States shall implement these Recommendations to the greatest possible extent;
- **International Documents (OIML D)**, which are informative in nature and which are intended to harmonize and improve work in the field of legal metrology;
- **International Guides (OIML G)**, which are also informative in nature and which are intended to give guidelines for the application of certain requirements to legal metrology; and
- **International Basic Publications (OIML B)**, which define the operating rules of the various OIML structures and systems.

OIML Draft Recommendations, Documents and Guides are developed by Technical Committees or Subcommittees which comprise representatives from the Member States. Certain international and regional institutions also participate on a consultation basis. Cooperative agreements have been established between the OIML and certain institutions, such as ISO and the IEC, with the objective of avoiding contradictory requirements. Consequently, manufacturers and users of measuring instruments, test laboratories, etc. may simultaneously apply OIML publications and those of other institutions.

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Additionally, the OIML publishes or participates in the publication of **Vocabularies (OIML V)** and periodically commissions legal metrology experts to write **Expert Reports (OIML E)**. Expert Reports are intended to provide information and advice, and are written solely from the viewpoint of their author, without the involvement of a Technical Committee or Subcommittee, nor that of the CIML. Thus, they do not necessarily represent the views of the OIML.

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Foreword by the Author

The OIML Seminar on Smart Meters, which took place in Brijuni, Croatia on 2-5 June 2009, was organized to bring together relevant stakeholders in the legal metrological aspects of smart metering: manufacturers, users (utilities and consumers), authorities (regulators, inspectorates), and conformity assessment bodies, together with the Secretariats of the relevant OIML Technical Committees and Subcommittees.

The Seminar was hosted by the Croatian State Office for Metrology, and its main purpose was to enable the OIML to take note of recent developments in smart metering (technologies and regulations, experiences and lessons learned) and to investigate the impact on the international harmonization of legal requirements for utility meters.

Fifty experts from 23 countries participated, representing national authorities, the European Commission, industry, standardization bodies, OIML Technical Committees and Subcommittees, and the BIML.

After a series of presentations and discussions, the following two main conclusions were drawn:

a) **For utility meters, it is the opinion of the participants that metrological control extends to the point where the consumer can verify that the measurement results used for billing are consistent with the reading of the meter.**

b) **As a follow-up to this Seminar, it would be appropriate for the OIML to develop some kind of guidance paper for those OIML Technical Committees and Subcommittees that deal with utility meters, containing suggestions for the application of OIML Documents D 11:2004 *General***

requirements for electronic measuring instruments **and D 31:2008** ***General requirements for software controlled measuring instruments*** **to utility meters and for additional requirements and (immunity) tests to be considered.**

It was suggested that the task of developing such a guidance paper could be performed by an ad-hoc working group. Considering the time constraints and the limited 'shelf life' of such a guidance paper, it was considered more efficient to publish it as an OIML Expert Report rather than to allocate this task to an existing OIML TC/SC as a new work item.

CIML Members were therefore invited to nominate experts to participate in the WGSM (*Working Group on Smart Meters*); experts were required to have appropriate experience relevant to the subject (i.e. legal metrological requirements for, and testing of, utility meters).

The outcome of the work of the WGSM is hereby published in the form of this Expert Report, which should be considered as the expression of expert opinion to provide guidance to the relevant OIML Technical Committees and Subcommittees in implementing requirements for measuring instruments having remote control and/or reading of data. The content of this Report is not specifically restricted to utility meters but should be especially helpful in the development of new Recommendations or the revision of existing Recommendations on such measuring instruments. It provides the necessary information on how to accomplish the relevant OIML objectives and explains how to decide whether to include additional performance requirements.

In Chapter 5 a rationale containing considerations, assumptions, restrictions, and statements is presented containing the current approaches presented in OIML publications that are considered applicable to smart meters and smart meter systems.

Chapter 6 describes a further legal metrology approach in general terms of the smart meter system as a whole, taking into account its environment of use.

Chapter 7 further focuses on the more practical evaluation by subdividing the system into a number of "black boxes" and discusses the practical way of evaluating and establishing the required tests.

This first edition of the Expert Report is intended to give some initial guidance. Readers are requested to collect comments and experiences when implementing legal requirements for these complex interconnected measurement systems. Feedback will be of great value for future editions of this Report and should be addressed to the author Mr. George Teunisse (gteunisse@verispect.nl) with a copy to the BIML (willem.kool@oiml.org).

Introduction

When laying down performance requirements for measuring devices to be used for legal metrological control, OIML Technical Committees and Subcommittees need to make decisions as to the extent of these requirements and the severity of the tests to be performed so as to guarantee the quality of a measurement and to reduce disputes over the results.

With the growing complexity in interconnections of measuring instruments and systems, the degree of legal metrological control that is required must be observed in a more detailed way.

Systems containing multiple measuring devices can easily grow to the size of large networks of devices when one takes into account all the interconnections; legal metrological control over such extensive networks is not readily feasible. In order to monitor the metrological aspect of such systems it is necessary to restrict legal metrological control to only those parts of a system that could influence the measurements and parameters which form the basis of a legal transaction. But restricting legal metrological control to only the primary measurement action itself may be insufficient, for example in those cases where this primary result is not recorded in such a way that its original value can be reproduced from recorded results and/or data.

Part -

1 Scope and objectives

The scope of this Expert Report concerns guidance for preventing violations of measurements and measurement data in instrumentation that is or that can be connected to a remote data collection and control unit, and that is to be used for legal control.

It does not deal with acceptable intervention on the measurement result, nor does it deal with incorrect interpretation of these results, and is restricted to violation of measurement results only (both accidental and intentional).

The main objective is to provide guidance to OIML TCs/SCs on the decisions to be taken and the options to consider in selecting and incorporating the necessary performance requirements for the measurement devices and systems within the scope of this report.

2 Abbreviations

BIML	Bureau International de Métrologie Légale
EM	Electromagnetic
ESD	Electrostatic Discharge
ETSI	European Telecommunications Standards Institute
GPRS	General Packet Radio Service (mobile data communication system using GSM)
GSM	Global System for Mobile communications
IEC	International Electrotechnical Committee
OIML	Organisation Internationale de Métrologie Légale
PLC	Power line Communication
PLT	Power Line Telecommunication
SC	Subcommittee
TC	Technical Committee
UTC	United Telecom Council
WGSM	Working Group on Smart Metering

3 Rationale

Implementation of the performance requirements for instruments in use for legal metrological purposes requires a rationale. Therefore, in this Expert Report some basic considerations and assumptions are specified which result in a number of statements.

3.1 Basic considerations, assumptions and restrictions

Considerations are expressed regarding the following performance related subjects:

- suitability of design (general performance);
- integrity of measurement results (are they prone to fraud);
- uniformity of performance requirements (metrological compatibility);

- acceptable risk (degree of confidence).

This is followed by an assumption concerning coverage by existing Recommendations and the description of the scope.

3.1.1 Suitability of design and integrity

The purpose of legal metrological control is to ensure that instruments are fit for their intended use, that they meet and maintain the necessary metrological performance requirements, and that they provide adequate protection against misuse, incorrect interpretations of results and fraud (from OIML D 1, V 4.4).

3.1.2 Uniformity

In order to achieve international uniformity and compatibility of measurements and to create the appropriate level of confidence in measurement results it is necessary to harmonize the performance requirements for measuring instruments and to harmonize the testing procedures aimed at demonstrating the equivalence of performance for the measuring instruments (from OIML G 17, 1).

3.1.3 Acceptable risk

One of the conditions for maintaining the performance of a measuring device is a negligible risk of unauthorized or unintentional interference or disturbance of the metrological information.

Hardware configurations as well as applied software are considered to have an impact on the degree of risk, which will also depend on the environment of use.

3.1.4 Assumed coverage by existing Recommendations

It is assumed that existing Recommendations already cover the measures for preventing hardware interference for those individual instruments whose connected cabling only serves for power supply or for interconnecting a measurement sensor with the unit or device which converts the analogue signal from the sensor into a measurement value.

3.1.5 Scope of legal metrology

In the case of utility meters used for residential consumers, legal metrological control is considered to extend up to the point at which the consumer can verify that the measurement results used for billing are consistent with the reading of the meter.

3.2 Statements

As a consequence of the considerations and assumptions the following can be stated:

3.2.1 Suitability of design & integrity

The primary concern from a legal metrology point of view is the integrity of measurement results and uniformity in performance requirements of measuring devices.

Sufficient hardware measures shall be taken in order to maintain the integrity and security of the device.

3.2.2 Software security

Any software security leak is considered unacceptable when metrological data can be accessed. Sufficient software measures shall be taken in order to maintain the software integrity and the device security, which includes a continuous survey of potential intrusions.

3.2.3 Acceptable risk

Risk assessments are needed on hardware as well as on software intrusion.

3.2.4 Scope of legal metrology

No restrictive performance requirements shall be described for parts of a measuring system which do not deal with, or have influence on, the value or stored value of the primary measurement result.

3.2.5 Innovation restriction

Legal metrology performance requirements shall not restrict the application of innovative techniques for measurements and for handling measurement data for which the essential metrological requirements on integrity and uniformity have been validated.

4 Legal metrology approach to smart metering systems

4.1 Definitions

4.1.1 Definition of a smart meter in terms of OIML publications

A smart meter is considered to be a measuring device (for utility metering) which is equipped with functionalities enabling certain parameters and data of the device to be remotely influenced, observed and acted upon.

4.1.2 Definition of a part of a measuring system in terms of OIML publications

A measuring system in terms of OIML publications is considered to contain one or more measuring instruments, each equipped with one or more devices or modules.

4.1.3 Definition of a module in terms of OIML publications

Note: OIML B 3 [2] contains the following definition for a “module”:

> Identifiable part of a measuring instrument or of a family of measuring instruments that performs a specific function or functions and that can be separately evaluated according to prescribed metrological and technical performance requirements in the relevant Recommendation.

4.1.4 Describing a smart meter configuration and its environment

Contrary to traditional stand-alone measurement equipment for utility metering, the configuration of a smart meter as a result of its definition includes certain interconnecting means and transmission related software.

Observing the assembly and its environment, the smart meter configuration can be considered as a network system and may contain a number of wired or wireless interconnected measuring instruments, which:

- are used to measure different measurands;
- are possibly installed quite close to each other; and
- contain functions/modules that convert the measured values into binary numeric electromagnetic quantities which become available as so-called digital signals.

4.2 Analysis of measuring systems

4.2.1 Metrologically relevant parts in general

To be able to define whether a function/functionality of a physical module is to be considered as metrologically essential, it is necessary to know its influence on the *metrologically relevant* output data.

Therefore, when observing the configuration of a measurement system an analysis should first be carried out indicating which functions within this system or part of such system could be considered as being essential for its metrological behavior and/or of relevance to its application for legal purposes.

The parts attributing to or comprising these functions shall be taken into account in the subsequent evaluation.

The next stage will be the analysis of whether and by what means such functions could be approached and/or influenced by external sources other than the measurand.

4.2.2 Metrologically relevant parts (functionalities) of smart meters

Considering its scope as presented in 3.1.5 and 3.2.4 , legal metrology should primarily focus on keeping data available for verification of billing.

The smart metering concept concerns the measurement of a cumulated quantity value coupled with the period of measurement and time dependent tariff. This implies that next to the recording of the quantity of the measurand, the time stamp registration is also of interest to legal metrology.

So the parts or modules at least to be included are those involved in the measurand quantity value recording and the time stamp registration. Any function/functionality which could influence these recorded values is of interest.

In principle, there is no need to include those parts concerning the applicable tariffs since this parameter does not tend to be the result of a measurement of its value.

As explained in 3.1.4, it is assumed that for this Report there is no need to deal either with the requirements concerning the accuracy of the individual measurement, or with the effect of influence quantities to which a standalone measurement device is exposed, since this is already covered by existing applicable Recommendations.

This Report will further concentrate on the extra measures it is necessary to take for the smart meter concept, which implies mainly extending to functions concerning adequate data storage and securing of data storage and transmission.

4.2.3 Analysis of the smart meter design

In addition to the evaluation of the correct metrological operation of a (module of a) system itself therefore, an analysis is needed of whether the stored parameters and recordings are secure, and also

whether all the possible (available) interfaces/interconnections of the system to the environment (and the manner in which these could serve as an entrance port for undesired influences) are secure.

As a consequence, it is necessary to include of all the available input and/or output ports to the environment, and also the expected behavior of this environment itself.

For this, it is necessary to break the system down into, for example:

- the several constituent parts of the measuring system;
- the environment; and
- the interconnections (input and output ports).

Following this, those parts that are relevant to the measurand or that could influence the measurement result may be defined.

The following distinction in devices based on metrological relevance can be made in the assessment of the measures taken to prevent incorrect measurement results:

Devices with internal recording of data

For devices that are designed to record measurement results, the assessment of the risk of loss or violation of data in the record is to be applied. Besides the measurement data from the measurand this also concerns other possible parameters of importance to the result used for transactions, such as recording the time and time interval measurements.

Devices without internal recording of data

For devices that do not record measurement data but instead transmit it to some data collection point, it should also be assured that the risk of violation of data as a consequence of transport through the data transmission medium is diminished.

4.2.4 Assessment of risk on violation

To further assess the risk it is necessary to distinguish between accidental and deliberate violation of measurement data, which need to be approached in different manners.

An influencing phenomenon as described below includes human intervention.

Assessment of the risk of accidental violation

Knowledge of the techniques used in a specific device can be a basis for a preliminary estimation of the potential sensitivity of certain influencing phenomena. It can also be a source for establishing the significance of a disturbance in relation to its dwell time.

a) **Observing the device**

Risks of violation of integrity by accidentally influencing the measurement or the measurement result could arise from inadequate design, which in turn could be caused by insufficient knowledge by the designer of the causes of a potential sensitivity of this design to a disturbing phenomenon.

In principle, a survey on measures taken during the design to prevent such a risk could provide the necessary confidence. This could, for example, be the approach when assessing software measures.

The risk of accidentally influencing measurement results caused by weaknesses in hardware design, however, often cannot easily be estimated on the basis of only observing the construction or design of the specimen.

Another risk concerns the possible mutual interaction between different adjacent electronic measuring devices, for example the effect of heat emissions from devices present in the vicinity. Specifically in the case where electromagnetic interference is concerned, it will be difficult to ascertain the number of potential EM leaks (which increases with the number of input and output ports), thus making the assessment of the risk of interference rather complex.

Moreover, the sensitivity of a measuring device to potential disturbances could also change if additional or alternative cabling and/or other auxiliary devices are connected.

In most cases it will therefore be necessary to detect weaknesses in hardware design by exposing such instruments or systems to simulated disturbance sources, which implies that some knowledge of potential disturbance phenomena and sources and basic knowledge about the way in which such phenomena may penetrate into a device is required.

Available sources of information

OIML D 11 provides an overview of available test methods concerning EM disturbances that are most applicable to measuring devices used for legal purposes.

Restriction

To assume that the requirements and tests described in the relevant standards and other guidance documents cover all the necessary needs for prevention of interference, amounts to neglecting the consequences of the rapid innovations in electronics. It is almost impossible to keep up with these fast developments and to ensure that they are taken into account in available standards, as the drafting of standards naturally lags behind such developments.

Therefore, a general requirement on non-interference shall be the guideline on the approach to take, and the analysis of the measuring device shall not be restricted to only testing against available standards.

b) **Observing the environment**

While in operation, each device is exposed to and more or less "influenced" by its environment. This environment is considered to comprise not only the "usual" physical environmental parameters (such as the rated operating conditions) but also the results of the emissions and/or influences from other instruments or devices located in the neighborhood.

With this definition of the environment it can be stated that each disturbance of a device in operation originates from the environment in which the disturbed device is located, unless the disturbance is produced by the device itself or the behavior of the measurand.

Knowledge of the (behavior of) the parameters that make up the environment is therefore essential.

For some environmental parameters, for example the climatic conditions of the in-service locations, a survey could be sufficient to ascertain their value or range of values. For others - for example those establishing the electromagnetic environment — this information cannot easily be assessed and/or measured since the frequency of occurrence of the EM phenomena could be too low. A better approach would be to use inventories such as those laid down in standards and/or reports.

Available sources of information

Much information on the worldwide EM environment is available[1)]; many standards have been written and much legislation is in force based on this information.

When successively taking into consideration the influences on the environment due to the presence of adjacent instrumentation, the approach could be similar to the above and the information collected on the environment could be combined with the known (maximum) emission of the adjacent instrumentation. On basis of the dimensional and other location parameters the latter could be calculated. For example, the maximum radiated heat emission from such instrumentation could be calculated from its location (and path) in the direction of the measuring device and the power consumption, while the maximum expected exposure to electromagnetic radiation from a device could be calculated from the (limits of) EM emission specified in the relevant EM emission standards and the path properties.

c) **Use of harmonized documents and standards (to reduce risks)**

As indicated, suggestions for requirements and test methods to eliminate the influence of a number of environmental phenomena are presented in OIML D 11. Most of these are based on international (IEC) standards. Although this horizontal document covers many influence factors, the performance requirements needed for protection against mutual interference specifically related to a smart metering concept are not yet completely covered by D 11. The latter in particular concerns the emissions and immunity requirements for data communication signals.

Moreover, attention should be paid to the fact that the presence of several instruments in close proximity to each other will give rise to mutual interference despite the fact that each instrument may satisfy the requirements in the standards.

For example, at a distance of a few cm from an antenna used for GPRS, one could expect levels above $10\ Vm^{-1}$ in the MHz band and at a distance of a few cm from a mains supply adapter one could expect levels of $0{,}1\ mT\ (= 80\ Am^{-1})$ at mains frequency.

Furthermore, in the near past it was proven that photovoltaic devices used for generating electrical energy can produce LF (kHz) band disturbances on the connected mains circuit which lead to deviations in the measurement results of the connected smart electrical energy meters.

In principle, the requirements and protocols specified in UTC and ETSI harmonized standards on telecommunications should cover securing and protection of the communication. The focus of these standards, however, is mainly on higher frequencies and on medium to long distances. Prevention of disturbing in-house (near field) and low frequency interactions are less covered.

Assessment of the risk of deliberate violation

a) **Observing the device**

The risk of violating integrity through deliberately influencing the measurement or the measurement result could arise when insufficient measures have been taken in the design so as to protect against such violation.

Since the measurement principle in most cases will be publicly available knowledge, a method for influencing a measurement will often be within reach, which implies that each design will need

1) An overview of potential sources of disturbance is available in IEC 61000-2-5 (in revision; Ed. 2 forecast publishing date: 2011-08)

some means of protection against potential fraud. In principle a survey on measures taken in the design to prevent such a risk could provide the necessary confidence. Again, this could be the approach when assessing software measures.

The risk of deliberately influencing measurement results caused by weaknesses in the hardware design depends on the direct or indirect[2)] accessibility of the parts and circuits involved in the measurement and to what extent measures to detect interventions are implemented. Again, a survey on measures taken at the construction and design stages to prevent such a risk could provide the necessary confidence. Furthermore, the measures taken to prevent an unacceptable and more or less predictable response to the higher level of interference should be assessed, which could be the case for (high level) magnetic or electromagnetic interferences.

Note: An interference resulting in a purely random response could be interpreted as a deliberate violation but *de facto* need not be considered as a fraud action.[3)]

b) **Observing the environment**

Concerning the deliberate influencing of measurements, the disturbing source is also part of the environment, such as a human being involved or the software routine in use.

Since an inventory or a complete listing of all the conceivable ways of influencing is not feasible, the only way in which one could make some discrimination is to distinguish between instruments that can be approached by the public and those that can only be approached by personnel in their line of duty.

Reduction of risks

A rather conventional means of preventing deliberate interference with the measurement result is the use of adequate hardware sealing and securing methods.

Unauthorized approach/amendment of software can be prevented by use of passwords and cryptographic means. The implementation of the principles/requirements as described in OIML D 31 could provide the necessary protective measures.

5 Evaluation of metrologically relevant parts of measuring systems

Hardware, firmware and software protection measures are needed to satisfy the performance requirements.

5.1 Hardware evaluation

5.1.1 Modular approach

When establishing the performance requirements and when performing tests on smart meters, breaking these systems down into modules has the following advantages:

2) ”Indirect accessibility” means through using some physical phenomenon.

3) Although a random response is most likely, protection by means of a checking facility such as some kind of “tilting” detecting could provide the performance protection needed.

- a smart metering system in many cases already comprises a number of modules, the configuration of which can easily differ;
- for some tests it is almost impossible to expose the smart metering system as a whole;
- when applying a modular approach the focus of the evaluation performance can be restricted to only those modules which have an influence on the legal metrology results.

A disadvantage is:

- practical results concerning the response of the system as a whole are not available prior to the installation.

Performing tests on a system as a whole, however, would only be useful for testing the mutual influence between devices installed at exactly the same distance from and orientation to each other.

While these geometric parameters tend to be rather random, tests on mutual interference will be very complex. A subdivision into modules combined with signal simulation is therefore more appropriate.

- **Identifiable parts (instruments, devices or modules; whatever is applicable)**

  To arrive at an overview for the purpose of setting requirements and performing tests, a (smart) metering system can be considered as consisting of a combination of identifiable parts.

  For each of these parts the model below may be applied. Each part, stand-alone or as part of a (measurement) system, can be considered as a black box with a number of input and output ports.

- **Definition of an input or output port**

  For the purpose of this Report, an input or output port of a device is considered as being each physical channel through which a connection is or can be made between the electronic circuits in this device and:

  - another device; or
  - a network; or
  - the electromagnetic environment.

  Such a connection may be established by making use of a physical product/medium (for example a cable) or a physical phenomenon (wireless).

- **Kinds of ports**

  A measurement device/module may comprise several ports having identical or different functions. Such physical ports may be used for different purposes which may be sequential or simultaneous and which make use of one and the same connection.

  Note 1: The enclosure of a device is also to be considered as being an input and output port.

  For example, distinction between the following kinds of ports may be made:

  - (power) supply port;
  - measurand input and output port;
  - data transmission port;
  - signaling and switching ports;

- enclosure port; and
- operator panel.

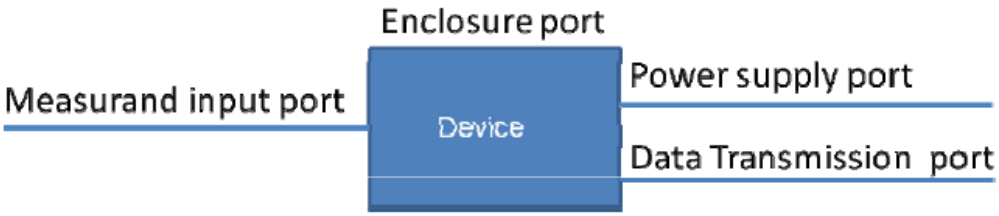

Figure 1 — Input and output ports of a device

- **Multi-function ports**

An example in which a port is used for more than one purpose is the connection of an electrical energy meter to the mains power supply. In this case the wires are used for:

- transmission of the electrical energy;
- electrical energy supply to the energy meter;
- data transmission line.

Another subdivision could be made for data transmission, and one could even distinguish between data transport and pulses mainly for switching purposes. The data transmission can include the electrical energy meter measurement data.

Each of the input and output ports can potentially influence the measurement data.

Each type of port, on the one hand, has to withstand improper intervention and on the other hand should not emit or produce a phenomenon to such a level that it leads to a disturbance on one of the other ports.

Note 2: Emission of EM disturbances is generally not considered in legal metrology requirements for measuring instruments.

When observing the different ports, the influence quantities listed below should be taken into account.

1 Power supply port

The device will need to withstand or filter out the following disturbances from the power supply port:

- mains voltage interruptions;
- mains voltage variations;
- mains voltage surges and bursts;
- all communication signals;
- induced radio frequency currents (antenna behavior).

2 Measurand input port (analogue)

The device will need to withstand or filter out the following potential disturbance from the measurand input port:

- induced radio frequency currents (antenna behavior).

3 Enclosure port

The device will need to withstand or filter out the following potential disturbances from the enclosure port:

- temperature/humidity fluctuations;
- electrostatic discharges;
- induced currents from radio frequency sources (antenna behavior);
- induced currents from power frequency sources including harmonics (near field coupling).

4 Data transmission port

The device will need to withstand or filter out the following potential disturbances from the data transmission port:

- data transmission line surges and bursts;
- out of band communication signals (signals for which the port is neither specified nor reserved);
- out of band induced radio frequency currents (signals for which the port is neither specified nor reserved).

5 Operator port

The device will need to withstand or filter out the following potential disturbances from the operator port:

- electrostatic discharges;
- induced currents from radio frequency sources (antenna behavior);
- induced currents from power frequency sources including harmonics (near field coupling).

5.1.2 Potential influences/disturbances and limitations

Generally speaking, influences or disturbances are the result of the presence of or change in physical phenomena that influence the measurand, but not the measurand itself.

- **Spectrum of phenomena**

  The behavior of the phenomena can be quite diverse. The values of the climatic parameters generally do not change as fast as the electromagnetic phenomena.

  Also, the nature of these physical phenomena can be quite diverse. For example some are only one-dimensional such as temperature, humidity and air pressure while others are multidimensional, such as vibration and electromagnetic phenomena. Another parameter which has to be taken into account and which differs quite a lot between phenomena is the dwell time.

  This difference in behavior will influence the risk on the measurand; the risk assessment approach should therefore be fitted to this behavior.

Table 1 — Nature of phenomena that are potential sources of influence

Physical phenomenon	Range dimensions	Orientation; polarization	Frequency	Dwell time
Temperature	1			Medium-long
Humidity	1			Medium-long
Air pressure	1			Long
Vibration	4	x	x	Short-medium
Magnetic	1	x		Short
Electric	1	x		Short
Electromagnetic	3	x	x	Ultra short-short
Chemical				Long
Etc.				

- **Actual coverage by performance requirements**

  Over the past 20-30 years, performance requirements for measuring instruments that are exposed to influences and disturbances on the enclosure port have been implemented in OIML Recommendations for a number of phenomena. Influences on the measurand (internal, external) have been taken into account, but the actual risk of such disturbances in most cases has not been addressed.

  For phenomena having a long or medium term dwell time this risk can easily be estimated. It has more or less already been taken into account by specifying the rated operating conditions.

  For short and ultra-short dwell times the risk cannot easily be estimated, but in general the appropriate requirements and test levels are copied from generic IEC standards and are based on experiences on interference in practice. Therefore, these levels should implicitly take into account the risk of interference.

  For some phenomena (see below) no performance requirements have yet been specified. One could assume that disturbances as a consequence of these will be covered by the general performance requirements of the measuring device. The risk of a disturbance, however, will be unknown when the dwell time of the phenomenon is short and its existence is location dependent.

Table 2 — Actual coverage by standards referred to in OIML D 11 and in the applicable Recommendations

Infl./dist. / Port	Power supply	Measurand	Enclosure	Data transmission	Operator
Climatic/vibration					
Magnetic					
Electric					

Table 2 *(continued)*

ESD					
Interruption					
Variation					
Surge/burst					
RF induced currents					
LF induced currents					
Rad. out of band					
Cond. out of band					

	Not applicable
	Could be applicable
	Covered in OIML D 11
	Partly covered in D 11
	No standard available
	Covered by UTC/ETSI

- **Low frequency phenomena**

  As can be seen from Table 2 for a number of relatively low frequency conducted and radiated phenomena, standards are not available and/or standardization is in progress. Caution is therefore advised and it may be necessary to develop and perform product specific tests.

- **Mutual interference of instruments in the same vicinity**

  One should be aware that the levels for EMC immunity testing as specified in generic IEC standards do not cover the risk of mutual interference between adjacent instrumentation.

  It could be expected that manufacturers in such cases will notice any undesirable behavior during prototyping. But this approach would not cover the potential interference from a device from some other manufacturer, which for example would be the case when power line communication is also in use next to the smart meter data communication line.

- **Estimating the level of interference from radiating sources**

  When attempting to estimate the level of electromagnetic interference, the following parameters need to be assigned a value:

  - expected environment of operation;
  - level of immunity of the measuring instrument.

Both tend to be complex but considerable research has been carried out and studies provide some figures on expected maximum levels of emission of sources.

When determining the properties of the environment, all contributing sources and distances from these sources are to be taken into account.

When determining the expected level of immunity, a mathematical model could be used or immunity tests could be performed. Both could be rather complex.

Simple but adequate models and/or reproducible test setups should be created.

One approach could be to base the deduced level of interference on the maximum expected emissions and optimal coupling between the sources and the "victim". The outcome of such an approach would probably be that some (perhaps most) of the instrumentation would not be in conformity with the requirements for non-interference.

Another approach could be to include a risk analysis, taking into account both the actual risk when a potential source is present, and the coupling factor. This factor would comprise e.g. distance, polarity and isotropy components, each of which contributes to the resulting intensity on the victim location.

Such an analysis can be performed using a mathematical model, but setting up such a model requires additional work. A Monte Carlo approach could probably be the best technique to estimate the risk.

- **Coverage of immunity tests**

Over the past ten years an exponential increase in the use of the electromagnetic spectrum has been observed, mainly for communication purposes. This accounts for both transmission line bound and free space phenomena.

Driven by commercial incentives the telecommunication companies have optimized the use of the limited available EM bandwidth by using sophisticated and intelligent software methods.

This increase in use, however, has not kept pace with the limited bandwidth available and the techniques for exploiting the upper RF bandwidth regions; therefore, the potential risk of conflicting use of the spectrum is increasing.

For decades, standardization committees have been intensively working on preventing mutual interference by setting requirements on emission and susceptibility of (mainly) electronic devices.

Their first focus on EM interference originated from the prevention of disturbance of radio services.

Besides this prevention of evident interference risks on communication, standardization of EM interference-related qualities further arose from hazardous incidents and commercial pressures.

However, since the occurrence of an interference in many cases is stochastic in nature, protective measures and standardization of these measures have only been implemented in those cases where there is a relatively high risk of occurrence and where there are substantial consequences.

A review of the agreed measures as specified in standards over the whole EM spectrum shows that this process has lead to an incomplete coverage of EM interference protective measures, resulting in certain gaps in specific bands.

The introduction of smart metering has made these gaps in protection more manifest.

One gap which has become more prominent concerns the VLF and LF band protection. Due to the fact that in this band below 150 kHz no (efficient) radio transmissions are operated, there is no real concern and therefore no involvement of radio protection agencies in this band. The use of EM phenomena and signals in this band is merely transmission line bound and emissions to free space are beneath the level of observance (noise level) within a few meters of the transmission line.

Electricity suppliers and distributors make use of this frequency band for switching and signaling over mains power lines. Since instrumentation connected to the mains will in general frequently be exposed to such signaling and since its properties are well defined, the risk of unexpected interference will already become prominent at the design stage of such instruments, and can be reduced prior to marketing the product.

Of more concern are those mains connected products which produce disturbances in this frequency band and whose waveforms are more or less arbitrary pulses. Smart meters, when directly connected to these mains power supplies, can suffer from these kinds of signals, not only as a result of the interference on the measurand but also on the measured data when using PLT/PLC as a means of communicating this data.

No adequate measurement methods or standardization are applicable for these kinds of interferences.

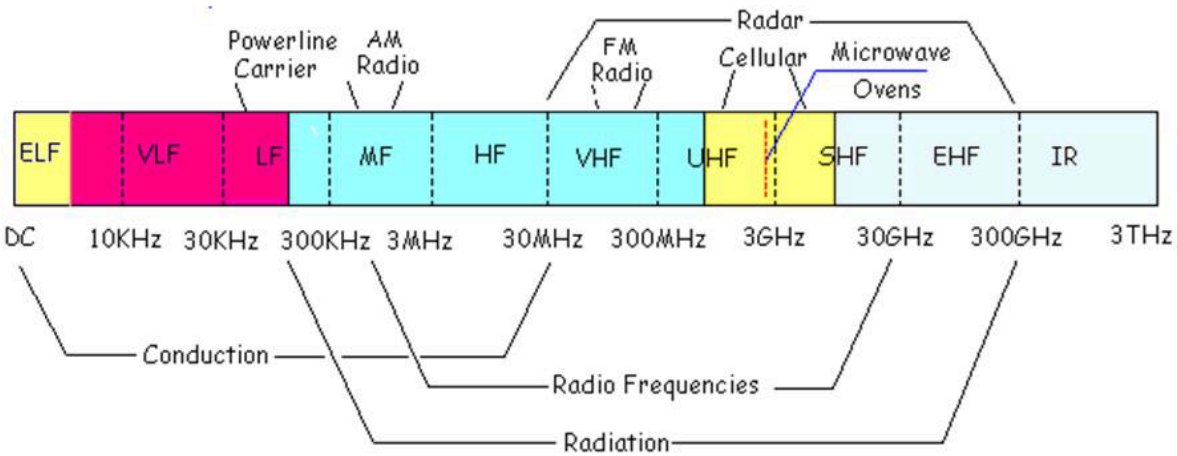

Figure 2 — Overview of the electromagnetic spectrum in use for radio and infrared communication

Frequency bands in use for smart metering are:

- VLF and LF (conducted) band for PLC;
- UHF band (radiated) for GPRS.

5.2 Software/firmware evaluation

5.2.1 Modular approach

Unlike hardware evaluation, the software evaluation of a complete smart metering system as a whole would in most cases be an impossible task.

A modular approach is the only practical way of evaluating software.

In principle, the constituent parts of the system are to be evaluated and data in an insecure environment is to be protected. Refer to OIML D 31 for such an evaluation.

5.2.2 Potential influences/disturbances and limitations

The need to evaluate the parts of the system depends on the location of the primary registers in which the results of measurement quantities and the associated time intervals are stored. The need to evaluate data transmission securing measures will depend on this location.

Furthermore, the smart metering software/firmware should include the securing of adequate time recording which, in turn, implies accurate time-stamping and interval measurement which are of sufficient resolution.

Time measurement can be performed to a very high degree of accuracy when using up-to-date techniques. In principle, this should not limit the accuracy in establishing the overall result of the measurements, but attention has to be paid to synchronizing and to avoiding delays as a consequence of processing and transmission. The securing of the synchronizing method and means shall be such that the accuracy of the time measurement has no consequences on the overall measurement result.

6 Conclusions

Secretariats of OIML TCs and SCs are advised to consider the additional functionalities of utility meters to first analyze their possible effect on the legal metrology aspects.

These aspects will need to include not only the actual measured quantity but also the time stamp in the case where measured values are accumulated.

Applying the device input-output model as presented in this Report, it is expected that one will become aware of the possible influences or interactions between parts of the systems and that adequate requirements will be implemented to prevent undesired hardware interactions.

These could be requirements for immunity to environmental influences created by emissions from adjacent instruments and possibly also for the level of the emissions to the environment. Parts (but not all) of these are at present covered by the provisions suggested in D 11.

Concerning software, it is assumed that when choosing a protection level the applicable provisions in OIML D 31 can be selected. These provisions will not only need to cover the securing of the measurement data related to the measurand, but also take into account the time-related measurements.

Inclusion of requirements for data transmission communication depends on whether these data are relevant to the ultimate verification of the transaction parameters.

Annex A
(Informative)
Some guidelines for estimating the risks of EM interference