

Feasibility study for a conformance testing centre

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Foreword

This feasibility study describes environments, procedures and methodologies to be adopted to establish, manage and maintain a testing centre covering different kinds of conformance and interoperability testing areas. Best practices also cover all relevant aspects not only related to test campaign activity, but also to all activities necessary to manage and maintain a large test centre.

The way in which new ICT technologies and infrastructure quickly develop has the power to affect the growth of economies and societies of both the developed and developing world.

I have no doubt that this study for the establishment of a conformance testing centre will help to support policy makers, regulators, manufactures, service providers and entrepreneurs through an understanding of future demands on a valuable and finite resource.

Many issues, challenges, questions and possibilities have been addressed in this report; it offers an overview of the technological changes and administrative challenges that all ITU member countries are facing and outlines the possible future trends in light of developments of laboratories in the vast set of domains, just to name a few: safety, mobile terminals, electromagnetic compatibility, interoperability, and so on.

The trends outlined here, in addition to the current BDT work on defining countries needs for conformance and interoperability infrastructure are part of the ITU integrated work towards promoting the best practices available in the world to developing countries.

This feasibility studies is part of the conformance and interoperability programme planning and therefore reflects much work already carried out in the *ITU Guidelines for Developing Countries on Establishing Conformity Assessment Test Labs in Different Regions* (2012) and the new *Guidelines for the development, implementation and management of Mutual Recognition Agreements (MRAs) on Conformity Assessment* (2013). I encourage you to make use of these valuable sources of information to the benefit of ICT users.

I hope that the guidance, milestones and timeframes set out in this study for the establishment of a conformance testing centre will support and guide our Membership, and in the long run, greatly benefit their citizens.

Brahima Sanou

Director

Telecommunication Development Bureau

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1 Objective of the feasibility study

1.1 Scope

This feasibility study describes environments, procedures and methodologies to be adopted to establish, manage and maintain a testing centre covering different conformance and interoperability testing areas, including best practice recommendations.

Value of testing

The most straightforward way to estimate the value of testing is by calculating the losses avoided, in terms of money, time and human life. Risk analysis is made in order to define the most appropriate testing strategy, by evaluating the impact of possible malfunctions with reference to the most important requirements. The evaluation may be qualitative, but whenever possible, it is reasonable to give also a quantitative evaluation, and balance any anomalies that have been detected (in terms of prevented damage or loss) against the benefits of testing, in addition to considering the cost of testing activities (in terms of resources). Further analysis would consider the impact of any future damages and costs related to the moment when the anomaly would be detected in operation.

Acquired knowledge

A further value of testing is given by the know-how obtained during the execution of testing activities. The expertise is related to the analysis of the requirements translated into a real solution, configuration aspects referred to services, equipment and environment, the knowledge of interfaces and related protocols and of the expected behaviour. For a telecommunication operator, it is often an opportunity for the personnel having a direct technical and physical contact with pieces of equipment in a testing environment.

Integrated vision

The orientation of testing activities to efficiently simulate all functionalities of ICT networks, (equipment, services, interworking, external environment, etc.) means that testing is often the first time that all the different elements composing the chain are put together. It is therefore in the testing environment design phase that it is possible and necessary to deepen the detailed analysis and architectural combinations definition, and identify critical situations.

Critical view elements in a 'mature' testing area

Testing in a mature situation according to international standards enables specific experience of the tester role, identifying risks and preventing anomalies that could seriously impact safe deployment in real operation conditions.

This allows an up-stream evaluation of the reliability of providers, identifying products that could generate unacceptable costs and delays. This could also help providers to refine their forecasts on availability of products/services, on the basis of previous experience and statistics.

Test environment – troubleshooting

Building such a test environment will allow subsequent troubleshooting activities to identify failures or defective functioning during critical situations at implementation that were unforeseen in the initial requirements. Due to the time needed to build and study a troubleshooting environment, only a working test plant already prepared during previous phases is compatible with a cost benefit balance.

Historical documentation

The documentation of test results may be of high value for customers. For instance, helping operator purchasing departments in the choice and negotiation with providers, identifying weak points (e.g. interoperability faults), and highlighting the probability of delays in provision. It can also be of guidance to an efficient incoming quality verification process.

In a regulated market, the test results can be used by surveillance or investigative activities by contributing relevant information for the recording of overall conformance assessments.

1.2 Content overview

The content of the document is organized in order to cover the many different aspects related to testing centre management and maintenance:

- resource management and organization;
- vendor management;
- test list life cycle and management;
- investment and cost estimation
- test campaign management;
- test plant and laboratory management;
- quality aspect;
- testing laboratories and test plant infrastructure.

Resource management and organization

This section covers all aspects regarding the management of the test centre resources, in terms of know-how, maintenance, skill selection and organization, use of international standardization activities and European projects to keep the centre updated. Information is also provided in relation to staff organization and structure and concerning all procedures related to human resources management.

Vendor management

This section reports suggestions to be taken into account in the relationship with vendor management. In particular it is very important to correctly transfer the testing activity to vendors in order not to delegate too many of the most critical activities. A good balance must be maintained between insourcing and outsourcing the major activities. High value-added test procedures must be controlled by the test centre while more operative configuration procedures can be left to external resources. The correct sharing is very important to maintain the correct know how and market control.

Test list life cycle and management

In the testing process it is critical to correctly design and maintain test lists used by the different testing laboratories. On the one hand the test list must be very detailed in order to cover all functionalities and reduce the risk of areas not being covered, but on the other hand a detailed test list requires a long test period and higher costs. Reducing the test lists can be in some cases necessary in order to shorten the time to market and the testing time as a whole. For these reasons it is sometimes suitable to perform light “credibility tests” only evaluating the most critical functionalities that have been identified.

Investment and cost estimation

An important aspect of the test centre management is the correct estimation of investments and costs. Taking into account the rapid evolution of ICT technologies, it is necessary to identify the correct areas of investment in relation to the evolution of networks and equipment to be tested. Usually the investment curve is not linear but has technological gaps and a typical example is the evolution of mobile network (GSM, HSDPA, LTE, etc.). Total cost of ownership in relation to new investment must be taken into account when evaluating the complete life cycle of each single investment. Special attention must be also paid to the purchasing process, defining detailed specifications and correctly organizing the call for tender.

Test campaign management

A central point of the management of a testing centre is the capability of correctly processing the test campaign. To perform the evaluation of a product effectively, it is necessary to follow different steps in

order to identify all possible anomalies. The usual procedure is to start the process by performing the *stand alone* testing (conformance testing), evaluating the functionalities and technical requirements of the single equipment as a black box against national/international/region standards and, after the end-to-end testing, emulating the real network in a test plant with possibilities to test the performance of the ICT product (benchmarking). Using this approach it is possible to identify in the first phase anomalies related to hardware and / or software and, in the second phase, any possible problems related to service models. Usually, after these two phases, customer field trails and service stability evaluations are necessary.

In this section an accurate analysis is also reported in relation to all tools needed to support the test campaign management such as bugs tracking procedures, use of specific mailing lists, and software release upgrading methods.

Test plant and laboratory management

In parallel to the testing activities there are many other correlated aspects that must be controlled in a test centre. In this section an overview of the security procedures to be adopted in terms of access control and risks during the testing activity is reported. Furthermore guidelines to maintain laboratories, test plant and instrumentation set up are given in relation to energy and environmental aspects.

Quality aspect

This section describes the procedures and methodologies to be adopted in order to maintain the test centre in accordance with the international standards on quality, in particular, great attention has been dedicated to the application of ISO/IEC 17025 standard, the international reference standard for laboratory management. Referring to this standard, it is possible to correctly design resources, test set up, processes, documentation and in general all aspects related to quality improvement and maintenance.

Testing laboratories and test plant infrastructure

The appendix of this report lists the most important laboratories to be established in a testing centre, covering the full range of ICT technologies. Information on test services, test set up, logistic and reference standards are reported. Some general information, concerning a fixed and mobile test plant, are also provided in order to realize an environment which is able to reproduce the real networks.

Table 1: List of testing laboratories and test plant

Testing laboratory acronym	Area of competence
SAR	Specific absorption rate lab
USX	User experience lab
BBA	Broadband access lab
VAS	Mobile value added services lab
EPS	Electrical safety and protection lab
ELA	Electroacoustic lab
EMC	Electromagnetic compatibility lab
RSL	Radio and signalling lab
PWE	Powering efficiency lab
QML	Quality of material lab
WIF	Personal area network lab
TPF	Fixed test plant
TPM	Mobile test plant

2 Necessity of conformance and interoperability testing

2.1 Conformance testing and protocol testing

The development of complex systems with complex functionalities requires the exchange of information between these systems. For example, communication equipment needs well defined rules to communicate successfully. Most of the theory and the formal descriptions related to conformance comes from software testing and in particular from protocol testing.

A protocol describes the rules with which systems have to comply in their communication with other systems. A protocol entity is that part of a system that takes care of the local responsibilities in communicating according to the protocol. The definition of these protocols is fundamental for the interoperability of equipment from different manufactures.

Many protocols are not developed in isolation, but within groups of manufacturers and users, with the aim of standardizing such protocols. This has led for instance to the development of the OSI Reference Model for Open Systems which serves as a framework for a set of standards that enable modern systems to communicate. However, in order to assure successful communication it is not sufficient to specify and standardize communication protocols. It must also be possible to verify that the implementations of these protocols really conform to these standard protocol specifications. One way to do this is by testing these protocol implementations. This activity is known as protocol conformance testing.

In the design, specification and analysis of protocols the use of formal, mathematically based methods increases. This makes it desirable and possible to found testing of protocol implementations on formal methods as well. This report deals with the use of formal methods in protocol conformance testing.

2.2 Testing process

Testing is the process of trying to find errors in a system by means of experimentation.

The experimentation is usually carried out in a special environment, where normal and exceptional use is simulated. The aim of testing is to gain confidence that during normal use the system will work satisfactory: as testing of realistic systems can never be exhaustive - because systems can only be tested during a restricted period of time - testing cannot ensure complete correctness of an implementation. It can only show the presence of errors, not their absence.

Conformance testing is a branch of testing where an implementation of a protocol entity is tested with respect to its specification. The aim is to gain confidence in the correct functioning of the implementation, and hence to improve the probability that the implementation will communicate successfully with its environment.

Conducting testing, experiments, or tests must be systematically devised. These tests are applied to an implementation, and the test outcomes are compared with the expected or calculated outcomes. Based on the results of the comparison a verdict can be formulated about the correctness of the implementation, which, if negative, can be used for improving the implementation.

In testing a clear distinction is made between **conformance testing** and **interoperability testing**.

Conformance testing

Basically, conformance testing is a procedure of product testing on compliance with requirements specified in applicable standards. The main goal of conformance testing of ICT products is to increase the probability that different implementations of the same standard will interoperate (ETSI ETS 300 406).

Conformance testing, also referred to as black-box testing, is based on the internal structure of the system under test. In case of software testing the aim is to exercise thoroughly the programme code, e.g. by executing each statement at least once. The system is considered as a black box, and the functionality is determined by observing it without any reference to the interaction with external entities. The main

goal is to determine if the right (with respect to the specification) product has been built. Tests are derived from the specification. A prerequisite for this kind of testing is a precise and clear specification.

In practical conformance testing the internal structure of the entity is usually not even accessible to the tester: the system in which the entity under test is located doesn't need to be accessible. The tester may only observe the entity by communicating with it.

Interoperability testing

Following the definition in ITU-T Recommendation Y.101, interoperability is the ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged.

In practice it turns out that functional testing of an implementation in isolation, i.e. conformance testing, does not guarantee successful communication between systems, products are also tested in a realistic environment, for example in a model of a communication network. In this kind of testing the interaction with other systems can be examined in more detail. It is referred to as interoperability testing.

Apart from testing the functional behaviour of a protocol implementation, other kinds of testing, test other aspects of a protocol, e.g. performance testing to measure the quantitative aspects of an implementation, robustness testing to examine the implementation's behaviour in an erroneous behaving environment, and reliability testing to test whether the implementation works correctly during a certain period of time.

Testing actors

Conformance testing can be performed by different parties. In general, the conformance testing against standards is the vendor's prerogative to test its product before selling it (ITU Handbook "Testing of next generation networks"¹). It really helps vendors to achieve and maintain the quality of developed products on the high level. On the other hand, users of products, or their representative organizations, test products for their correct functioning which comply with user requirements. Telecommunications administrations check products before connecting them to their networks to prevent malfunctioning of a network caused by incorrectly implemented products. Finally, independent third party test centres can perform conformance tests for any of the previously mentioned parties. A system of accreditation allows testing laboratories to certify implementations that they have been tested and judged to be conforming.

Standardization of conformance testing

If implementations of the same (internationally) standardized system/protocol are tested by different test centres it should not occur that they decide differently about conformance of the same implementation. Ideally, it should not be necessary that the same product is tested more than once by different testing laboratories. This is possible if testing is based on generally accepted principles, using generally accepted tests, and leading to generally accepted test results. To achieve this, the International Organization for Standardization (ISO) and ITU have developed a twin standard for conformance testing of open systems. This standard is the ITU-T X.290² (ISO/IEC-9646-1): 'OSI Conformance Testing Methodology and Framework' The purpose of this standard is 'to define the methodology, to provide a framework for specifying conformance test suites, and to define the procedures to be followed during testing', leading to 'comparability and wide acceptance of test results produced by different test centre, and thereby minimizing the need for repeated conformance testing of the same system'. The standard does not

¹ www.itu.int/pub/T-HDB-IMPL.09-2011

² <http://www.itu.int/rec/T-REC-X.290>

specify tests for specific system/protocols, but it defines a framework in which such tests should be developed, and it gives directions for the execution of such tests. The standard recommends that sets of tests, called test suites, are developed and standardized for all standardized protocols.

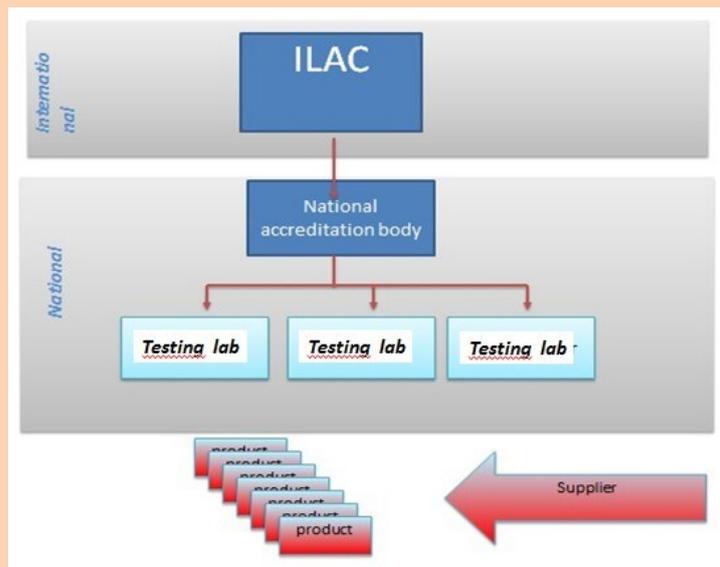
Accreditation of the test centre

Accreditation is the third party attestation related to a conformity assessment body useful for a testing laboratory to obtain the formal demonstration of its competence to perform a specific task. The reference standard is the ISO/IEC 17025. The testing laboratory accreditation is performed by national and/or international accreditation bodies. The accreditation on the international level is issued by ILAC³ (International Laboratory Accreditation Cooperation), IAF and IECEE.

Accreditation is performed by the national accreditation body (e.g. ACCREDIA in Italy, according to the EC directive 765/2008. The national accreditation body is recognized by the Italian government). Fulfilment of ISO/IEC 17011 requirements demonstrates that the accreditation body is competent to perform its accreditation tasks.

To mutually recognize the different national accreditation bodies ILAC was created in 1996. In 2010, the ILAC arrangement had 72 accreditation body signatories (full member) from 59 countries. The purpose of ILAC is to develop a global network of accredited testing laboratories that are assessed and recognized with the same processes and quality standard. Figure 1 shows the hierarchy of the approval process for an accredited testing service.

Figure 1: The hierarchy of the approval process



Source: ITU

³ www.ilac.org

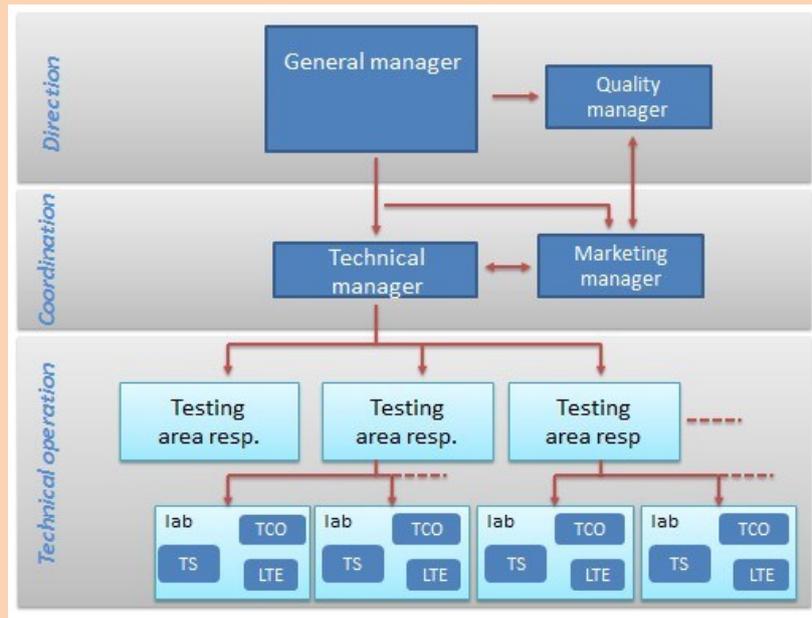
3 Resource management and organization

3.1 Organization

A conformance testing centre should be independent of any companies, so it guarantees its impartiality as a third-party provider of conformance testing services.

A typical organization structure and its key personnel is shown in Figure 2.

Figure 2: Organization chart



Source: ITU

3.2 Test centre staff

General manager (GM)

The general manager has the overall responsibility of the test centre development.

In detail, he or she shall:

- supervise and manage overall activities of test centre;
- direct the administrative and financial management of test centre;
- accept the advice and suggestions of the quality manager, and support the quality;
- produce and continuously improve the quality manual (section 10.1) and the relevant procedures;
- plan and direct the development of test centre, with the help of technical manager;
- establish the marketing policy of testing services;
- keep contacts with other bodies involved in the testing activity, in order to improve the technical knowledge of this area;
- review the reports from the quality managers and the technical managers, and give direction on key decisions;

- sign the contracts, licenses, agreements and so on with the customer;
- approve the employ of test centre personnel, and sign the contracts with the new employees.

Technical manager (TM)

The technical manager is responsible to general manager for the overall technical activities of the laboratory in accordance with the standards and procedures indicated in this quality manual and the requirements of national/international accreditation bodies. As technical manager is responsible for all aspects of the results of testing activities; he or she shall:

- plan and supervise the test services, ensuring that the activities and the quality of the test centre;
- assist general manager to find funding and resources to execute agreed work programmes;
- assist general manager to produce the development plan of the test centre;
- authorize and sign the test reports;
- authorize the acceptance of the new test-tools and the related technical procedures;
- supervise the implementation of any technical corrective action which may be found necessary in the course of activities;
- assist the quality manager to prepare quality plan;
- decide the use of technical staff in the test centre, with the approval of general manager;
- ensure that test centre staff is adequate and competent, and plan the training programmes with the assistance of the testing area responsible;
- establish together with the testing area responsible the programmes for technical improvement of services;
- convene and chair regular coordination meetings with the testing area responsible and the quality manager in order to examine qualitative and technical objectives and propose any necessary corrective action;
- have overall responsibility for site security of the test centre.

Testing area responsible (TAR)

Testing area responsible is responsible to the technical manager for coordinating and supervising the testing activities performed by the personnel in his or her area in compliance with the requirements indicated in the quality manual. His or her responsibilities include:

- checking the test reports issued by his or her area;
- allocating work among testing specialists;
- acting as the first contact to the testing specialist concerned when any queries are raised;
- assisting the technical manager to establish the programmes for technical improvement of test services;
- assisting the technical manager in planning the personnel training programmes, and arranging them;
- creating the technical area annex of the quality manual related to his or her area; verifying that the annex pertaining to his or her area is kept up to date at all times and updating this annex according to the requirements;
- being responsible for filing, updating and cancelling the technical documentation of his or her area;

- chairing regular meeting with his or her area personnel to examine objectives and propose any necessary corrective action;
- holding responsibility for controlling access to the testing area laboratory.

Testing specialist (TS) – test campaign responsible

Testing Specialist is responsible to the testing area responsible for the implementation of related conformance assessment in compliance with the requirements indicated in the quality manual. His or her responsibilities include:

- implementing the requirements indicated in the quality manual and the requirements of the testing services offered by the test centre;
- maintaining liaison with clients on technical aspects after signing of contracts;
- coordinating the test campaign;
- performing the conformance testing, including setting up the client's test environment, supplying all necessary information and materials to the client, reviewing the materials (PICS, PIXIT, etc.) submitted by the client, executing the test, analysing the test results, and preparing the test reports.

Test campaign operator (TCO)

The test campaign operator is responsible of executing the test campaign. His or her responsibilities include:

- accepting and installing the new/repared testing equipment;
- being responsible for the day-to-day maintenance work of testing equipment and recording them into maintenance workbook;
- being responsible of the execution of the test campaign;
- ensuring backups are carried out in accordance with the relevant procedures;
- acting as librarian for the equipment manuals and technical documentation of the area.

Laboratory technical experts (LTE)

This expert can be external to the laboratory and, in complex organization is not usually involved in the testing activity but can be part of the innovation or engineering department. He or she is the reference expert for a specific subject for the laboratory in term of knowledge evolution.

Quality manager (QM)

The quality manager is responsible for establishing and verifying the adequacy of the quality system described in the quality manual, ensuring that the requirements of the ISO/IEC 17025 are met on a day-to-day basis, and advising the technical manager and general manager accordingly. The quality manager is responsible to the general manager and also has a reporting line to the technical manager. His or her responsibilities include:

- establishing and maintain an overall view of the test centre quality system;
- verifying the quality procedures used by test centre and its areas, analysing the adequacy of each ones;
- organizing at least one formal quality review per year against ISO/IEC 17025 requirements and related standards;
- planning and organizing quality audits to ensure that at least one formal audit per year for each aspect of the quality system is carried out;

- reviewing the results of the audits, ensuring that the corrective actions are implemented;
- convening regular meetings for briefing all staff on the requirements of quality;
- supervising the management, maintenance, and distribution of the quality manual and quality control procedures.

Deputy quality manager (DQM)

The deputy quality manager reports to the quality manager and assists him or her to conduct his or her duties. In the absence of the quality manager, the deputy quality manager deputizes in all aspects of quality and takes over the responsibilities of the quality manager. He or she shall:

- assist the quality manager to plan and organize the quality review;
- assist the quality manager to plan and organize the quality audits, and conduct them;
- review the results of the audits with the quality manager, supervise the implementation of the corrective actions;
- maintain the summary and general part of quality manual and other quality documentation.

CSU manager

The CSU (central service unit) manager is responsible to the general manager for work in the CSU, including marketing, administration and secretarial works. He or she shall:

- promote the marketing of testing services;
- meet with the clients in order to introduce the services provided by the test centre;
- answer any question related to the procedures and rules raised by the clients;
- help the customer to issue the applications and have a preview;
- report the applications to the general manager;
- send and receive contracts;
- schedule the test campaigns, and assign the test campaign number for each;
- check the completion of the test campaign folder when the test campaign has been finished;
- receive any complaint from clients, explain to them, and report to the general manager and technical manager and quality manager about that.
- be responsible for accepting and returning the system under test (SUT);
- act as an interface to the suppliers of equipment;
- maintain records of all outside bodies from which test centre obtains services and goods;
- supervise the work of the test centre secretary.

Secretary

The secretary is responsible to CSU manager for coordinating the internal administrative activities and providing the general manager, the technical manager and the quality manager with operational support in secretarial functions. He or she shall:

- perform the day-to-day administrative activities for various areas;
- draft up relevant administrative documents for the services (contracts, etc.);
- create and maintain the qualifications and training records for each test centre staff and maintain the test centre staff list;
- register testing equipment and maintain the testing equipment registers;

- register, backup and store the master copy of PC software used for preparing test reports;
- attend to editorial changes and distribution of the quality manual and quality procedures;
- ensure the documentation relating to the quality system is complete and up to date;
- act as archive librarian for the quality and administrative archives.

3.3 Management procedures

In the following the management procedures to be adopted in case of absence of staff members are described.

- In the absence of the technical manager, the general manager takes over responsibility for the operation of the test centre.
- In the absence of a testing area responsible, the technical manager takes over responsibility for the operation of related area.
- In the absence of the quality manager, the deputy quality manager deputizes in all aspects of quality and takes over the responsibilities of the quality manager.
- In the absence of other personnel, the responsibilities involved are taken by the absent person's immediate superior.

Each member of test centre staff receives a copy of quality manual and a complete set of quality procedures. Each member of staff must read them carefully and familiarize with all contents involved in these documents, especially the extent and limitations of own responsibility, and use them in the day-to-day operation of his or her work. Regular meetings are convened by the quality manager for briefing all staff on the requirements of quality.

The test centre shall not be engaged in any activity that may endanger the trust in its independence of judgment and integrity in relation to its testing activities. It is responsibility of the management of the test centre to ensure that the independence of staff is maintained in all phases of their work.

The test centre and its staff shall be free from any commercial, financial and other pressures which might influence their technical judgment. The remuneration of the staff engaged in testing activities shall not depend on the number of tests carried out nor on the results of such tests. All the staff must judge independently and cannot be affected by any external factors. They must be warned about the seriousness of accepting inducements. If any of such things occur, they must inform the test centre management as soon as possible, otherwise all responsibilities are hold by themselves.

Each member of staff must clearly understand the importance of the protection of proprietary rights and information, and do his or her best to ensure that security procedures are enforced.

3.4 Staff qualifications and training

Testing service staff is trained for the tasks they are expected to perform. In order to achieve and maintain a high level of professional training on the part of operational personnel, the technical manager shall plan the training course with the assistance of the testing area responsible. The training should cover the conformance testing methods for the technical areas and the test tools used, as well as the general quality management aspects. In addition to these courses, which the laboratory normally manages in-house, personnel shall attend additional external courses conducted by test equipment manufacturers or organizations. Conferences and seminars on the aspects of testing or quality will likewise be attended.

For the reason that technical manager is responsible for the overall technical activities of the laboratory, more requirements is needed,

- being familiar with the test service process, test specification and test technique;

- knowing very well all test services provided by laboratory and the test specialists he or she used;
- knowing very well the status of test set up used in test services;
- knowing very well the requirement of ISO/IEC 17025 and related standards.

Qualifications and training records have to be maintained indicating the following for all personnel engaged in the test centre activities:

- job experience in each position held;
- educational background;
- level of on-the-job training;
- publications;
- attendance at seminars and meetings and visits to other laboratories;
- professional qualifications.

3.5 Periodical reporting

A good procedure to be adopted in order to manage in an efficient way the testing centre is to hold a periodical reporting session between the TM and the TAR to verify the status of the different activities. The QM can summarize the result of the weekly reporting session in a status report document. The status report document must be organized in order to keep track of:

- status of each campaign;
- main fault identified with gravity status;
- top issue of the week;
- critical point to be solved;
- liaison with other bodies or company entities and departments.

4 Vendor management

4.1 Vendor relationship

The relationship with equipment vendors is dependent on the type of organization to which the test centre belongs. For an independent laboratory, the equipment vendors are simply customers, and so the commitment to the test centre is defined by a bilateral agreement between the laboratory and its customer. For a laboratory that is part of a bigger organization, i.e. a test centre that is a department of a network operator, the equipment vendor can be seen as a “supplier”. In this sense, the relationship is not only managed between the test centre and the equipment vendor, but at a higher level.

A network operator could be interested in introducing new suppliers, and so the equipment vendor could be a “partner” in developing and fixing the new services. In that case, the customers of the test centre are the departments in its own organization, interested in introducing new services (or new equipment), and so the equipment vendor does not pay any fee to submit new equipment to a testing campaign. The requesting department should consider the testing cost as part of the development and deployment cost.

In other cases, the equipment vendor itself could be interested in submit new products to the network operator, in that case the testing cost might be paid, at least partially, by the equipment vendor.

4.2 Joint testing (outsourcing – insourcing)

Where the relationship with an equipment vendor is a form of partnership, the working load for testing could be in some way “shared” between the test centre and the equipment vendor.

This can be exploited in different ways:

- The vendor presents the results of its own testing; the test centre examines the test results and chooses which are the tests to be planned: i.e., chain tests, or tests of critical importance.
- The vendor brings its own people to the test centre, in order to jointly perform the foreseen tests.
- The (most important) tests are completely performed by the test centre itself, and the vendor concentrates its effort to the development of the new product / service (taking into account the test results).

However, the test centre should concentrate on the most important tests, in order to better control the most critical results, and to evolve the competence of the test centre's staff by following the state-of-the-art technology.

4.3 Testing park

An innovative way to use the test centre facilities is what we call a testing park approach.

An equipment vendor, or a consultant, that is not adequately provided with own test facilities, could "rent" the test centre facilities, in order to conduct testing by itself (possibly with a support from the test centre staff).

This situation is quite new when the test centre is not an independent one but, for example, is the laboratory of a network operator.

Besides an improved exploitation of the laboratory facilities, this approach could allow the test centre to expand its knowledge to test areas near its core competencies, but beyond its usual activities portfolio.

5 Test list life cycle and management

In this section, some general concepts about the design and maintenance of a test list are given. The details of single laboratories are not addressed here (see the appendix on test centre services).

5.1 Design

The design of a test list shall take into account, as a first point, the objective of the testing.

Type approval testing

The test campaign that produces a formal type approval certificate requires a test list which is defined by the standards. The test list shall cover all the topics foreseen by the standard; in some cases the standard itself also defines the test list that has to be followed and the minimum requirements (regulated by national/region rules).

Voluntary certification schemes

Also the schemes of voluntary certification resemble the type approval approach: there is an approved document that states the requirements that are to be tested, and possibly the test list itself. The test list shall accurately follow the stated requirements.

Introduction of new equipment / services to commercial use

When the object of the test is to verify new equipment or a new service before its introduction in a more complex system, i.e. in the operator network, or the launch on the market, the test list has to be carefully designed.

First at all, a “no regression test” phase shall be foreseen: the test list shall ensure that the new equipment/service does not jeopardize what previously used to work correctly.

Then, the new features have to be tested: the test list shall verify every new aspect that is introduced by the new product / service, from a functional point of view. In this phase, an analysis of the communication protocols can be foreseen.

At the end, performance aspects shall be tested, where applicable: for instance, the data transfer speed in different environments, the delay, the audio quality, etc.

The test list design shall take into account the schedule of the activity: i.e., the depth of the analysis shall be balanced with the time foreseen for the testing phase; the test list shall however cover all the most important aspects that are identified considering the needs of the final user.

Credibility testing

Credibility testing refers to testing conducted in an earlier phase of the product development, i.e. in great advance to the market introduction. In that case, the objective of the testing is to assess the potential of the new technology / product, so the test list should be more focused on the innovative features and, on the performance if it is a distinguishing feature. The no regression tests can be postponed to a more mature phase of the product deployment.

In case of comparison between different products / different vendors, the test list should ensure that the results are objectively measurable and comparable.

5.2 Maintenance

In case of type approval or voluntary certification schemes, a test list shall be maintained and modified when the relevant standards change.

In case of testing for introduction to commercial use, the test list should be “customized” on the features of the new service / equipment. The test list should indeed ensure the verification of the most innovative features. The compatibility with the existing eco-system shall be in every case guaranteed; the no regression tests can often be adapted from previous test lists.

In case of credibility testing, the test list should always fit to features of interest.

6 Investment and cost estimation

The availability of proper assets is a topic of paramount importance for a test centre. In particular, the wide areas of competence coupled with the rapid changes in technology determine the need to acquire and maintain the proper test equipment required for the setup of the desired test benches.

Decisions about new investments should always take into account the total cost of ownership of the new equipment: i.e., some equipment requires regular maintenance in order to ensure the proper functionalities and performance.

6.1 Investment areas

The main investments for a test centre fall into the following areas:

- technological gaps;
- evolutionary maintenance;
- instrumentation duplication (efficiency improvement);
- support systems (simplification and automation).

Technological gaps

Technological discontinuities pose important milestones where a test centre has to decide if it shall offer test services on the new technology or not. Often these discontinuities need to allocate a significant budget. The risk is however a rapid obsolescence of the test facilities, if the new technologies and standards are not followed.

A significant example of this area is the introduction of LTE in a mobile radio network. A test centre shall acquire new test equipment, i.e. test terminals, network simulators, protocol analysers, etc. able to cope with the new system. To complete a test offer, also specific facilities should be foreseen: in the given example, it could be an anechoic chamber specifically equipped with a MIMO (multiple input multiple output) test set-up.

Evolutionary maintenance

The area of evolutionary maintenance is a “smoother” technological improvement, but equally essential. Evolutionary refers to all kinds of maintenance that are not usually included with the maintenance contracts that are often maintained by a test centre.

For example, a protocol analyser that does not need to be replaced with the introduction of a new standard, but that needs the upgrade with new boards and new software licences. While this example is quite similar to the case of “technological gaps”, other examples can be the replacement of an old reference standard with a newer one, or the change of an EMC receiver. In the latter cases, the “old” instrument is still able to perform the required task, but its aging suggests the replacement with a newer one (that can be indeed more precise, more efficient, or also able to perform additional tasks).

Instrumentation duplication (efficiency improvement)

A test centre is able to perform up to a defined number of test campaigns, depending on the available test facilities and equipment, and on the test list that is to be followed. When the required volume of tests increases in a certain test area, and the use of the test bench is already optimized, the test centre has the option to duplicate a specific test bench.

In case of duplication for the improvement of the testing throughput, often the safer solution is the replication of the test bench with the same instruments. When programmes for the automatic control of the measurement are in place, the replacement of a specific instrument with another might not be straightforward and could require a significant effort in adapting the test suites. Also the expertise of the staff in using specific instruments should be taken into account.

Conversely, the choice of different instruments could be useful if the comparison between different test equipment is an added value for the specific measurement, or if instruments with slightly different capabilities offer more flexibility. In the purchasing phase, the availability of different instruments can be a good way of obtaining better prices.

Support systems (simplification and automation)

Besides the investments that are mandatory to be able to perform measurements on specific topics (i.e., on new technologies or new standards), some can greatly simplify laboratory operations. In this area we can consider the investments for the automation of test benches. These include the acquisition of software able to control the instrumentation, the development of automated test suites, or the acquisition of “off the shelf” automated suites (or test systems).

This kind of investment does not add specific “testing capabilities” to the test centre, but it improves the ability to perform the same tests in less time. In some cases, the automation of test suites could avoid the duplication of test benches by improving efficiency.

The automation of the tests is of great importance for test suites that are repeated many times in the same way: for example, for standard terminal testing or for the execution of no regression tests. In such cases, an efficiency improvement can give a significant competitive advantage to the test centre.

6.2 Investment priorities in relation to investment areas

The investment priorities need to be selected keeping in mind the objectives of the test centre, its customers and their needs. In general, a test centre should initially evaluate if it is necessary to follow new technologies and what instruments are needed to set up measurement benches on these technologies, as well as to elaborate a plan to keep pace with the new technological trends.

The evolutionary maintenance is necessary to maintain the capabilities of the test centre, so part of the investment budget should be dedicated to this area.

Only the volume of the requested tests determines if a duplication of existing test benches is needed. When the process improvement and the automation of the tests are not sufficient, the test centre should consider if the request of a particular area of test campaigns will be constant or even increase in the future. In that case, the duplication of benches can be a good option.

The automation of tests often require more investment in time and effort than in money. When some test campaigns are commissioned to the Lab, and the execution of the tests can be automated, the automation is generally a good investment: it improves not only the test throughput but also the repeatability, and often the accuracy, of the test campaign.

6.3 CAPEX: Total cost of ownership in relation to new investment

When a test centre considers acquiring new instruments, it should take into account not only the initial cost, but the total cost of ownership (TCO).

Some instruments require regular software maintenance to be aligned with recent advances in international standards. For example, a protocol analyser should be always kept in line with the latest software. A software maintenance contract could cost 10-15 per cent of the initial cost, for every year of use.

In some cases, a hardware maintenance contract could be useful, especially on the more critical instruments and when the test centre does not have alternatives to complete the test bench due to failure. Depending on the flexibility and on the efficiency of the internal purchasing process, to manage problems only when they arise could be a quite long and time-consuming process.

Some years of upgrades and free maintenance could be included in the initial purchase of the instrument: so, this should be taken into account when comparing different offers on similar instruments.

6.4 Opex: Instrumentation maintenance and service externalization

The budget of a test centre should consider two main categories of Opex: the maintenance of its instrumentation, and the externalization of some activities (if applicable).

Instrumentation maintenance

The proper maintenance of the instrumentation is an issue of great importance for a test centre. A test centre should have a careful plan to cover the instruments that:

- require a regular software maintenance (maintenance contracts) to keep their efficiency.
- require a periodic calibration and this should include the calibrations that the test centre can execute “in house” (if the test centre has an internal metrological service), and those that require an external lab.
- are critical and require a hardware maintenance contract with a service level agreement (SLA).

The expenses for maintenance and calibration are quite predictable and are part of the regular operation of a test centre.

Service externalization

A test centre should identify its core competencies and test capabilities, and should decide to commit some tests, which it is not equipped to perform, to external laboratories.

For example, a telecommunication test centre could choose to commit chemical-physical tests on the quality of materials that are requested only few times in a year and require very specific test equipment.

Purchasing management

In order to obtain the best economic conditions when purchasing new instruments, it should be useful to give different options to the purchasing office, and to set up a challenge between different potential suppliers.

To do so, the needs of the test centres should be expressed as a technical specification in terms of a “List of requirements”, specifying if the requirements are mandatory or optional. The test centre could also identify a list of instruments that can satisfy the requirements, and provide the list to the purchasing office, together with the technical specifications. The purchasing office will send out a tender to the potential suppliers. Among all the instruments that will satisfy all the technical requirements, the less expensive one should be chosen.

In some cases, the test centre should consider their technologic legacies when acquiring new instruments (for example: the test centre has automated test suites for a certain instrument, or so on); also in this case, launching a challenge to promote innovation on automated tests suites could help in obtaining better economic conditions.

7 Test campaign management

The test campaign management is a critical process in any testing centre. The efficiency of the process has a direct impact on the processing costs and time to market of tested products. Moreover the correct testing sequence is very important to identify anomalies in the item under test. Most testing centres adopt the testing sequence described in Figure 3:

- 1 **Stand-alone testing:** In this phase the product is evaluated as a single element not connected to the other equipment (test performed in lab).
- 2 **End-to-end testing:** In this phase the product is evaluated as a part of a network according to a defined service model (test performed in test plant). The estimation of the real ICT product performance might be a part of this phase (the special load equipment is necessary).
- 3 **In field testing:** The product is tested in real environment conditions (test performed in the field).
- 4 **Service stability evaluation:** Final evaluation of the end-to-end service performed using real customers/end users (test in field).

Figure 3: The four step testing process



Source: ITU

7.1 Testing process

Another important aspect to be defined is the process of identifying the roles and responsibilities of the testing centre staff, especially if the testing centre is part of a wider organization.

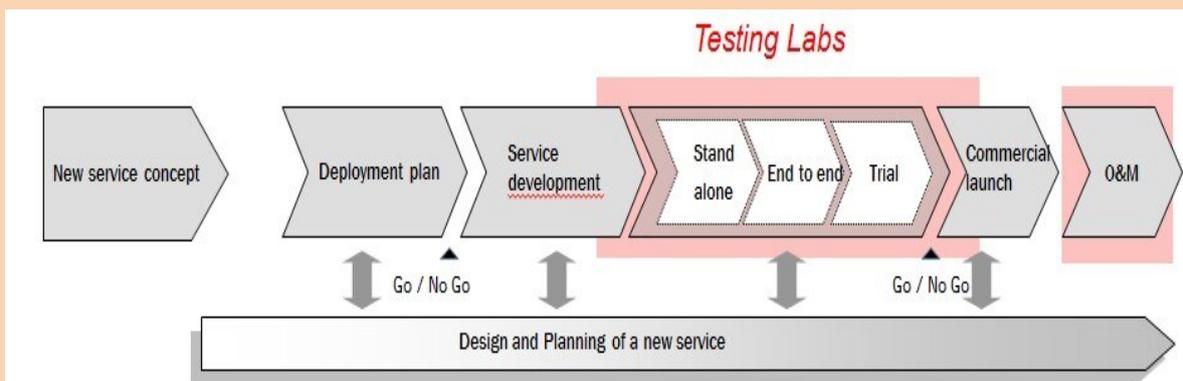
Figure 4 describes the typical process related to the creation of a new service and the role of the different departments. Usually the service concept is defined by the marketing department, as far as staff requirements and financial aspects are concerned, and in collaboration with the engineering department, which is responsible for the identification of technical aspects and limitations.

Once the service concept and deployment plan is in place, the detailed attributes and parameters to produce the service model and start the service are developed, and the the testing centre is then responsible for evaluating the correct implementation of the service and the validation process can start.

The validation process (in laboratory and test plant) can then be organized into the three initial testing sequence phases: stand-alone testing of the single element; end-to-end testing or chain testing; and field trial.

Once the service has been validated and launched, a service stability evaluation trial can be organized to verify possible problems related to service maturity. When the service is stable, the operation and maintenance phase can be implemented.

Figure 4: The service creation process



Source: ITU

Stand-alone testing

The first phase of the testing process is the stand-alone testing. In this phase the functions and features of the implementation under test (IUT) are verified. Different aspects related to hardware and software are tested in isolation. The tests are executed stimulating the EUT from standardized external interfaces with suitable instrumentation emulating protocols or performing physical measurements.

Usually stand-alone testing is organized in two parts:

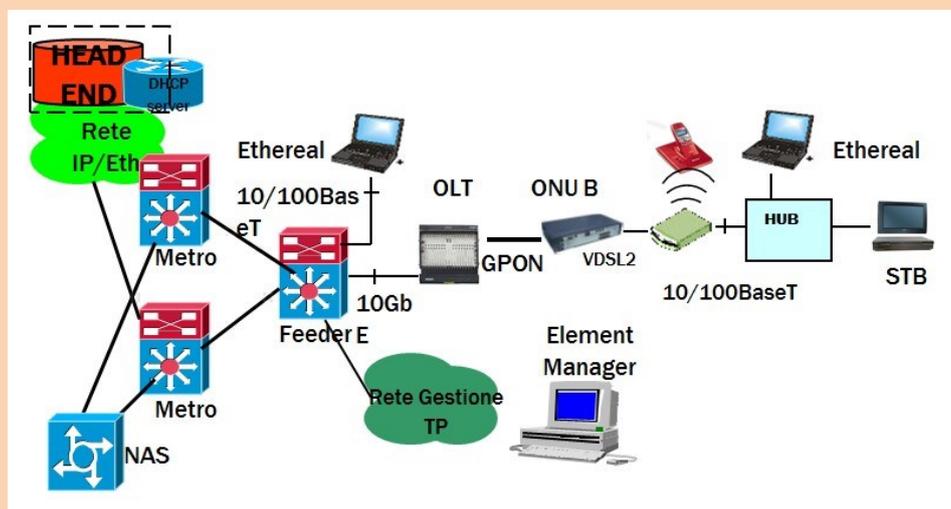
- **hardware related** testing phase in which physical parameters are tested such as EMC, powering safety and protection, radio, environmental (temperature, vibration), electrical/optical, etc.
- **software and networking** aspects testing phase in which the functionalities related to protocol are verified usually using protocol analysers.

End-to-end testing

After the stand alone testing phase, it is often necessary to evaluate the correct interoperability between the equipment under test and other elements. To execute these tests, it is necessary to reproduce a working environment, such as a telecommunications network, in a test plant using the most important network elements interconnected according to the service model identified during the service creation phase. In this test phase, all network element features and functions have to be represented from the service provision related equipment to the transport and delivery equipment.

Figure 5 shows the test chain necessary to validate equipment used to offer next generation access services (NGAN architecture).

Figure 5: NGAN end-to-end testing chain



Source: ITU

Typical test families, performed in the end-to-end testing phase, are tests on quality of service, performances, management procedures, traffic load etc.

Field trials

The field trials are usually performed when the laboratory (stand-alone) and test plant testing (end-to-end) is terminated and all evaluations executed in a controlled laboratory environment have been carried out. In this phase usually all main anomalies are solved and the behaviour of the new system in operating conditions must be evaluated. During the field trials, new equipment is installed in working networks that test, not only the performance aspects, but also all network operation processes like provisioning, billing, quality of service, maintenance, etc. In this phase, the ability of staff to install, manage and maintain the new network features, functions, and systems are also examined.

Service stability

After the field trial, the service stability evaluation is usually the last phase before the launch of the new service. To perform this activity, a test group of customers are identified to evaluate and monitor the quality of the new service. The target of this activity is to verify the customer experience of new services

and/or products, both in the pre-operational and the commercial launch phase, through on-site evaluations with ad-hoc and permanent groups testing features such as accessibility, functionality, and usability. The effectiveness of the trial process should be reflected in an improvement in quality and subsequent decrease in early failure rates.

The value of the test group can be summarized in three fundamental and distinctive areas:

- 1 the service-enabling environment is real (involving a physical network, real traffic and users);
- 2 the customer typology does not involve only technicians and people who are involved in the process or working on the development of new services but non-expert real users/customers;
- 3 the home environment, reflecting a spontaneous use in line with customer habits.

Figure 6: Service stability evaluation context



Source: ITU

To perform this kind of evaluation, it is necessary to follow a well defined methodology depicted in Figure 7.

Figure 7: Service stability evaluation methodology



Source: ITU

Trouble shooting

Due to increased network complexity, a great amount of effort must be devoted to interoperability testing, which ensures that all combinations of fixed and mobile access and terminals work.

This leads to a specific troubleshooting analysis that may be configured as a contingency test in order to absorb unexpected or unforeseen delays, anomalies, or losses without failing. This is particularly important when gaps in test coverage result in unacceptable defect detection rates with a high number of field failures. This activity may be conducted in a test plant that constitutes a small replica of the real mobile network (see appendix A) and uses commercially available mobile terminals.

In this case, adequate skills and availability of the assigned system administration support staff must be ensured, otherwise misconfigurations of complex test environments may result in errors (e.g. incident reports related to the environment and not to the mobile terminal itself).

The result of this activity is an extension of the existing test lists, in order to increase the testing coverage in the areas which seem to be less robust. Main inputs for these test list extensions may be generated from operation department feedback and/or the most widely reported anomalies by customer care complains, so a direct link with these areas is necessary. When the appropriate information is available, e.g. coming from the marketing department, a risk analysis for each model of mobile terminal (usually the most profitable and expensive models) may be applied to select the testing areas which need an in-depth analysis, and a preliminary phase of exploratory testing may also be envisaged in order to optimize the test planning phases.

7.2 Bugs tracking and test campaign management

A fundamental aspect in all testing processes is the correct handling of the storage and management of bugs and anomalies detected in the different phases: stand alone, end-to-end, field trials etc. It is important to use reliable tools in order to keep track of the gravity, ownership and history of each bug.

The best approach is to use dedicated software to manage all testing procedures. The commercial, or *ad hoc* application, usually adopted must be able to:

- plan test campaigns;
- trace test lists and test cases;
- manage product/service under test;
- manage laboratories list;
- trace bugs;
- export basic test reports;
- monitor testing activities.

A key aspect is to correctly store and manage anomalies with the right status of gravity in order to have a transparent relation with the vendor and inside the different company departments (engineering, testing, operation). Usually bugs are classified according to two indicators: severity and priority.

- **SEVERITY:** is the level of technical *non conformity* of the bug.
- **PRIORITY:** is the *level of solving* priority for the bug.

Usually four levels of severity are used: A (higher priority), B (medium priority), C (lower priority), and D (informative). In Figure 8 an example of bug classification is reported.

Figure 8: Example of bugs classification

Severity	Description
HIGH High technical non-conformance.	Very critical anomaly impacting one of more of the following functionalities: service, capacity/traffic, charging, O&M. Typically they cause a total or critical lack of service not avoidable with a workaround solution.
MEDIUM Medium technical non-conformance with respect to the attended results.	Important anomaly seriously impacting functionalities or performance of the system or the service offered, and/or O&M functionalities. Typically these anomalies can produce a low functional or performance degradation.
LOW Low technical non-conformance with respect to the attended results.	Anomalies not impacting the main system functionalities or the offered service. Typically these anomalies don't produce degradation in the quality of service or O&M procedures.
Informative Remark	Point of attention. Typically this behavior has no impact on the final service, but it is important to be taken into account for future requirements and specifications.

Source: ITU

In the anomalies management process, it is also very important to identify the role of the different actors in the test campaign in order to follow a correct hierarchy in the bug emissions and handling. In Figure 9, four different possible roles are listed from the tester level to the management layer. The role of each actor in the test campaign is identified by two parameters:

- **VISIBILITY:** indicating the level of intervention of the actor on the bug management.
- **ACTION:** indicating which kind of action is allowed.

Figure 9: Roles classification in anomalies management process

ROLE	Visibility	Actions
TESTER	Complete access to Test Track and Test Plan	Open/Reopen/Defer/Close bugs Change bug severity (H, M, L, I) Receive Email notifications
SOLVER	Read-only access to Test Track Read-only access to Test Plan except for change bug status: -from Open/Reopen to Accepted -from Accepted to Deployed	Change bug status (accepted, deployed) Receive Email notifications regarding only their own opened bugs
ENGINEERING	Read-only access to Test Track Read-only access to Test Plan except for change bug priority	Change bug priority (A, B, C) Receive Email notifications
GEST_1	Read-only access to Test Track and Test Plan	Receive Email notifications
GEST_2	Read-only access to Test Track and Test Plan	

Source: ITU

7.3 Release management

Equipment under test (EUT) can be varied with many different features and functions, ranging from a small access gateway, used to provide internet access, to big network nodes for metro or core networks.

Especially for such more complex systems, usually tested in a test plant reproducing the real network, it is important to correctly manage software releases under test. A good way to approach this problem is to have at least two samples of the equipment installed in the test plant with two software releases:

- **Current software release (N):** equipment using the release in operation used to emulate the service and for troubleshooting.
- **New software release (N+1):** equipment using the new beta release used for testing purposes.

7.4 Mailing list utilization

Nowadays, in complex test centres, all personnel, from manager to test operator, are interconnected with the IT infrastructure, and most of the communications are performed using e-mail. For this reason, in the test campaign management and in the laboratory and test plant, it is important to regulate the e-mail utilization and to create suitable mailing lists. The correct use of these tools could seem a minor factor but this has a strong, overall impact on testing process efficiency.

In the following some general rules and advice is given on how to correctly implement mailing lists. If well designed, mailing lists can impact on the speed and efficiency of management of the test campaign and hardware and software resources.

The most important rules to be taken into account are:

- It is useful in general to subdivide the laboratory mailing list from the test plant mailing list in order to avoid e-mail spamming among the users.
- Only share information relevant to a test campaign with involved test operators in order to avoid mail congestion.
- Share identified test solutions among involved test operators to avoid effort duplication.
- Keep track and share information of the status of the different equipment to correctly implement the test chains.
- Create mailing lists for instrument reservation from the different laboratories in order to have the efficient use of resources.
- Keep track of usage of equipment resources and ports through a hardware resources data base.

7.5 Implementation Under Test - UIT management

The correct management of the IUT is required to perform an efficient test campaign, and the following are suggestions to improve management, cost efficiency and risk reduction:

- Get the IUT from the vendor on loan especially when are cumbersome and expensive.
- Get more than one sample in order to run parallel tests in separate laboratories.
- Ask vendors to complete the equipment data configuration modules (e.g. ITU PICS proforma).
- Reduce power consumption of large systems by using only the port under test.
- Use databases to store the status and location of the different EUTs.
- Take out an assurance contract when IUTs are expensive.
- Use IP controlled socket to power the IUT when possible to reduce power consumption.

7.6 Measurement uncertainty evaluation

Measurement uncertainty evaluation is best described by GUM (Evaluation of measurement data — Guide to the expression of Uncertainty in Measurement).

“When reporting the result of a measurement of a physical quantity, it is mandatory that some quantitative indication of the quality of the result is given so that people who use it can assess its

reliability. Without such an indication, measurement results cannot be compared, either among themselves or with reference values given in a specification or standard. It is therefore necessary that a readily implemented, easily understood, and generally accepted procedure for characterizing the quality of a result of a measurement, that is, for evaluating and expressing its uncertainty.”⁴

The formal definition of the term “uncertainty of measurement” is as follows:

uncertainty (of measurement)

*parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measured value.*⁵

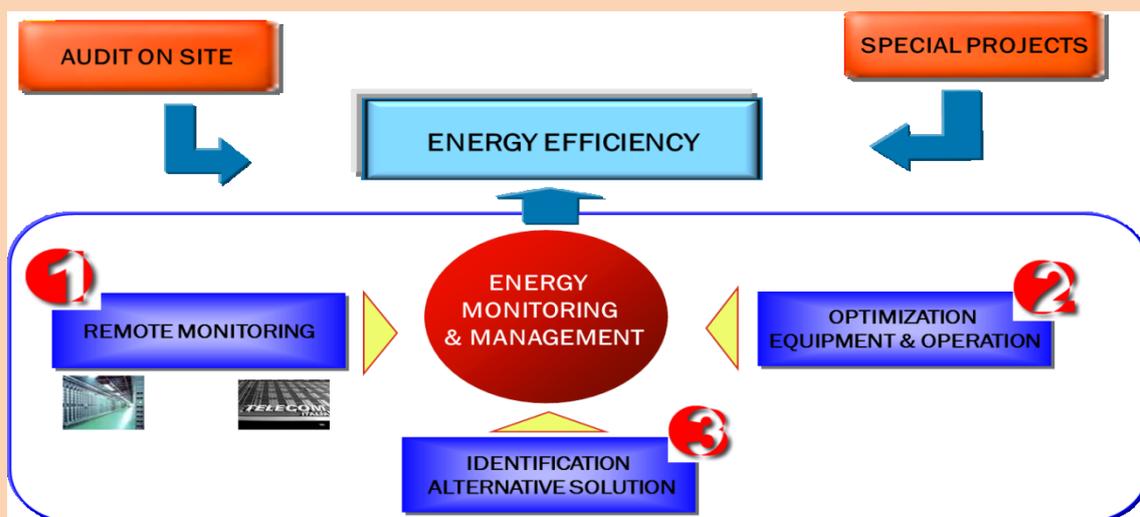
8 Test plant and laboratory management

8.1 Energy saving

The energy consumption is a topic that has increasingly acquired great importance all around the world, and a test centre should be aware of the issue, both for its own activities and to provide consultancy to its customers.

The first step in energy saving is to know what the power consumption is, and for this reason an effective monitoring system should be deployed. A number of solutions can be put in place to save energy.

Figure 10: Energy monitoring process



Source: ITU

Energy monitoring

⁴ www.bipm.org/utis/common/documents/jcgm/JCGM_100_2008_E.pdf Document produced by Working Group 1 of the Joint Committee for Guides in Metrology (JCGM/WG 1). www.bipm.org

⁵ Idem.

An energy consumption monitoring tool is a key factor in understanding the principal cost items and the relevant high consumption conditions. The measured information using the tool allows the main inefficiency items to be detected and then energy saving corrections can be made.

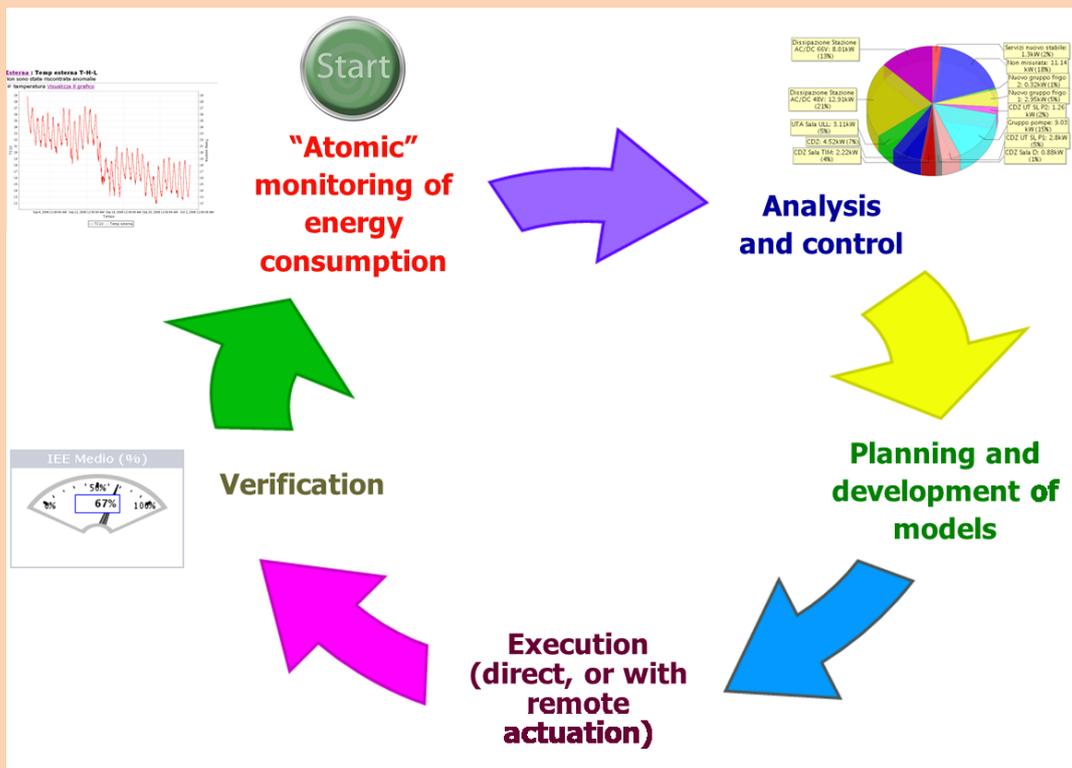
The lack of detailed information and measurements about the different power distribution areas (DC loads, AC loads, air conditioning systems, etc.) and about energy consumption items makes it difficult to:

- verify energy provider billing and to evaluate contractual aspects;
- understand the reasons for the difference between energy consumed and energy used;
- fix the right interventions needed and priorities;
- quantify the effects of interventions and evaluate the pay-back time.

For example, a tool based on a wireless sensor network (WSN) for remote monitoring, auditing and control the energy consumption allows the measurement of:

- environmental data: external and internal temperatures, relative humidity, light;
- energy consumption data: power/energy absorbed, detailed for ICT equipment and services.

Figure 11: The energy control cycle



Source: ITU

Saving opportunities

There are several options open for a test centre to implement energy saving policies. Energy consumption of telecommunication equipment is not specifically considered in this section - such as the power needs of equipment deployed in a test plant - and power consumption is specific for different equipment, and management procedures also vary, but this section does briefly address the topics of cooling, lights, and renewable sources.

Design of air conditioning / free cooling

It is important to distinguish between the effectiveness and efficiency of a cooling system:

- Efficiency is an indication of the amount of energy that is converted into cooling energy compared to the amount of energy supplied.
- Effectiveness indicates how the cooling energy cools rooms and equipment.

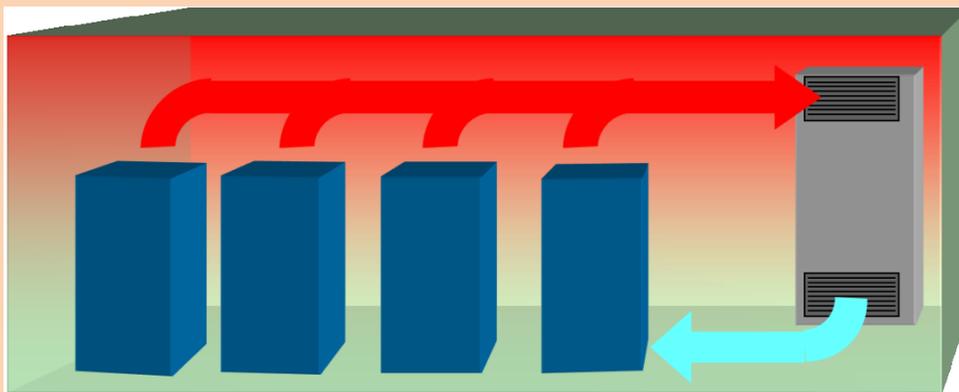
The effectiveness of the system (composed of the cooling system and devices) depends on several factors:

- airflow topology;
- position of equipment;
- the direction of flow of hot air from the equipment;
- hot spots management.

Some solutions to optimize cooling are:

- By sizing correctly the infrastructure via a modular architecture of climate and energy systems, it is possible to increase them if necessary and avoids the use of larger systems.
- Maintain the highest ambient temperature (25-30° C) that is allowed by the equipment;
- Remove hot air, possibly near the cooling devices.
- Install more efficient energy systems.
- Install panels for the containment of hot air is useful for reducing the areas of concentration of heat and save energy.
- Optimize the flow of cold air and avoid unwanted mixing of hot and cold air.
- Remove possible obstructions below the floating floor, cleanliness and layout of the cables which can disrupt the distribution of cold air.
- Since hot air goes up over, the best way to circulate the air in the room to be cooled is to suck hot air from above and enter the cold air from below.

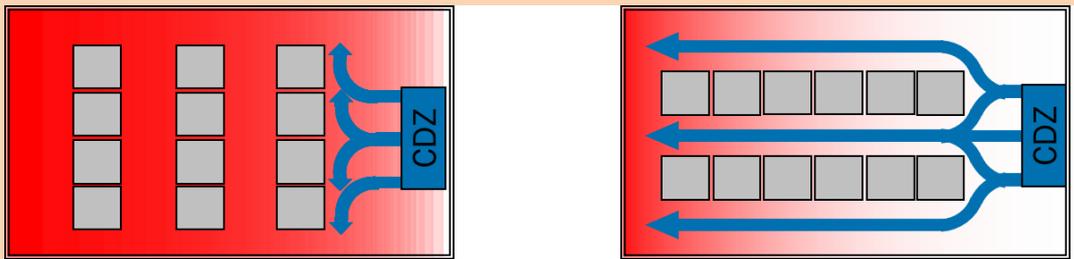
Figure 12: Cooling system air flow



Source: ITU

- Cold air from air conditioning systems must be able to expand to all points of the room.
- It is essential that air distribution is free of obstructions.
- If air is introduced directly in the room is important that the devices are positioned to allow the best air flow possible.

Figure 13: Cooling system air flow variations (obstructed and free flowing)



Source: ITU

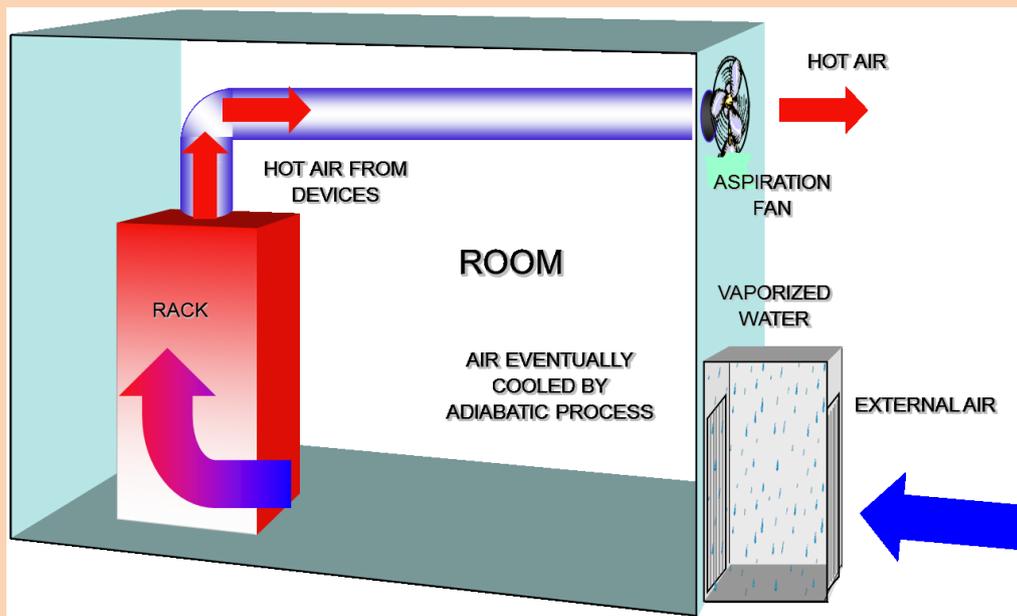
- The openings of hot air exhaust from the devices are generally in a horizontal direction. If the devices are badly placed the hot air from one device can be aspirated by another.
- Solutions:
 - place the equipment to create cold and hot aisles;
 - fit deflectors to direct hot air flows away from the emission nozzles.
- The cooling of the room is more effective when the temperature is uniform.
- The presence of hot spots (critical points where the temperature is above the average level) implies the need to reduce the overall temperature of the room to maintain the required temperature throughout.
- Devices that produce the most heat should not be grouped in one area of the room.
- If the devices that produce more heat need to be grouped, it will be necessary to isolate them to optimize the cooling zone temperature without affecting other areas.

An effective solution to cool equipment rooms, such as a test plant, can be the use of free cooling systems. The most innovative is the free cooling extraction, i.e. the air is extracted from the room as near as possible to the device and the cool air enters because of the depression created in room.

The free-cooling system has a low cost and reduces the need for air-conditioning. The operation period for a free cooling system is enhanced by means of an adiabatic humidification system, where inlet air is cooled without energy transfer (adiabatic transformation).

In summer, in particular hot regions, traditional cooling system can be used to provide the remaining cooling loads.

Figure 14: The free cooling method



Source: ITU

Low power lights

In Europe, new requirements on the energy efficiency for the lamps are in place. The halogen lamps and traditional incandescent lights were substituted and withdrawn from the market from the end of 2012.

Workarounds:

- Improved halogen lamps: energy saving 20-45 per cent for the same light quantity.
- Compact fluorescent lamps (CFL): energy saving 65 to 80 per cent of incandescent lamps.
- LED: as efficient as the CFL but without mercury and LEDs have longer life.
- The LED lamps are still in their infancy from an industrial point of view, and the costs are still high, but the sector is very promising. For the use in office environments, attention should be paid to colour, temperature and stability of the light. In Europe, there are a number of technical standards that shall be applied.

A significant saving can be obtained also by applying energy saving policies such as turning off lighting when no people are in the room.

Renewable sources

An energy production system, by means of renewable sources, can be applied to reduce the energy bill of a test centre.

The most common renewable generators are photovoltaic and micro-eolic:

- Eolic turbines have a good efficiency only for quite high wind speeds, i.e. 8-10 m/s. If the average wind is below 5 m/s, there are no available efficient eolic generators.
- The photovoltaic panels are applicable almost anywhere, providing that there is a sufficient surface, and preferably facing South.

For photovoltaic systems, costs are an issue and the return of the investment should be carefully evaluated although government incentives are often in place. Without any incentives, the return of the investment can be very long, especially in areas where the power from the grid is easily available and relatively inexpensive.

8.2 Environmental impact

A test centre can avoid unnecessary waste in its own operation, as well as reducing power needs and pollution by means of the results of testing.

In terms of the day-to-day operations, a test centre can monitor, and try to reduce:

- the overall energy consumption;
 - the energy consumption for heating/cooling;
 - the energy consumption associated to traveling;
- the use of paper (by means of extensive use of electronic documents);
- the (possible) production and correct disposal of hazardous waste (i.e., from a chemical laboratory or so on);

In terms of influencing the energy usage and the potential pollution, a test centre can:

- assess the energy consumption of equipment and power supplies;
- help in defining how to assess the electro-magnetic emissions;
- assess the eco-compatibility of products, for example by verifying the conformance to the EU RoHS Directive (restricting the use of hazardous substances in electrical and electronic equipment)⁶, or in general by identifying the materials used (to promote the use of more environmentally friendly materials).

8.3 Safety aspects

The management of a test centre shall always take into account the safety aspects. These aspects are regulated by national laws (for example, in Italy all the rules about safety aspects were collected in the law 81/2008). Knowledge of the applicable national laws is necessary.

The first step is a risk evaluation: the activities performed in the workplace are analysed in order to identify those that can potentially expose the worker to hazards.

Then, measures are established to reduce the risk as much as possible. These measures include:

- definition of working instructions;
- identification of individual protective devices;
- training about the risk factors, the work instructions and the protective devices.

The law identifies the people who are responsible for safety; for example in Italy, the safety is a primary responsibility of the employer, and then of the managers. Besides them, the law considers also the “appointed person”, that is the person who gives instruction directly to the workers. In a test centre, the “appointed person” can be the head of the single laboratory unit, and he is also accountable for the safety aspects.

The “appointed person” shall ensure that all the workers in the laboratory are aware of the risks, and, where applicable, that they have the proper individual protection devices, they know how to use them, and they use them regularly, following the working instructions.

⁶ http://ec.europa.eu/environment/waste/rohs_eee/

A periodic control of this and of the good functioning of the individual protecting devices is quite important, and the registration of the controls is required by some national laws.

The working procedures could also state that only people with a sufficient training, and considered fit and qualified, can perform some particular tasks (using the appropriate individual protective devices).

Any external firms must be supplied with the test centre working procedures and safety measures to be applied by the personnel of external firms that operate on the company premises. In this case, the test centre must also apply to the external firm for advice about existing risks and take the appropriate measures to define and minimize those risks.

The information about the risks shall always be given by an “appointed person”, either the laboratory manager or the coordinator of a specific activity.

The employer also has the duty to appoint, and to train, some employees for the management of emergencies and first aid. A plan for the evacuation of the site shall be defined and drills shall be periodically performed.

The offices and the laboratories themselves shall be designed (and maintained) taking into account safety needs: for example, escape ways shall be in place and maintained free of obstacles, proper doors shall be provided, etc. In general, the accumulation of flammable material shall be avoided, and fire extinguishers shall be in place.

8.4 Security and access control

Usually the access to working centre premises is regulated; this is even more so for laboratories, where there are valuable assets, and there are often safety rules that need to be known and respected.

An electronic tool that collects the requests for admittance to the premises, for external personnel, is quite useful. It allows the centre to define a period of allowance for an entrance permission for regular visitors (for example: suppliers, or maintenance personnel). A regular visitor could also be provided with a visitor badge that simplifies the access procedures.

An occasional visitor that is not registered in that tool should however always be tracked by the security personnel, and his or her stay in the company premises should always be accompanied by an employee.

Besides the entrance to the premises, access to individual laboratories could be further regulated, including for the employees. In particular, the accredited laboratories require a defined list of personnel who are allowed to enter and work in individual laboratories. The entrance to individual laboratories can be regulated with numeric keyboards or with badge access.

8.5 Instrumentation remote control

The remote control of instruments, via IEEE-488 (GPIB) or other interfaces, is a well-known option.

In a well arranged test centre, only a small number of measurements are performed acting directly on the instrument’s keyboard, most are made remotely for the automation of test suites.

Automation of test suites

The automation of tests is of great importance for all the test procedures that need to be repeated, in multiple test campaigns. The automation gives a number of advantages:

- Reduction of test execution time: an automated test suite is generally executed in a fraction of the time that would be needed for execute the single steps manually.
- Better repeatability: the automated execution eliminates the potential errors due to the operator.

- Improvement of efficiency: the operator does not need to follow step by step all the test execution, and can perform some other activities in parallel. In some cases, a test case / test suite can be launched during the night, or also during the weekend, optimizing the use of the test facilities.

Remote equipment configuration and computer remote control

Apart from the automation of a test suite, the instruments control via computer also allows remote control: in general, the operator does not need to stay in the same room with the instruments and the equipment under test.

- Network equipment can also be configured and controlled remotely, using the IP network.
- Power sockets that are controllable by an Ethernet port are also available, making it possible to automate operations that require the “hard” switch off of a device.

Such options allow the complete control of a test bench remotely, where “remote” can mean variously from “in the room nearby” to “from home” or “from a different city”.

Use of control rooms

The remote control of a laboratory or a test plant (a particularly noisy environment) from a control room, that is an “office-like” location, allows the employees to work in a more comfortable environment, where also the interaction with colleagues can be more effective.

The possibility to operate instrumentation and network equipment from a control room, also allows other options such as the tele-working.

Tele-working

The common use of control rooms, allowed by the ability to remotely control instruments and equipment, gives the possibility to adopt a partial tele-working also in a test centre.

The number of teleworkers can also improve the effectiveness of the test centre, because more employees are able to act remotely on the test bench at the same time and outside of normal working hours.

Almost all the activities needed in a test centre can be performed on an ADSL or a HSPA link (adequately protected by a virtual private network).

The teleworking framework must respect the national law and the company rules. In general, as stated above, a higher flexibility is an added value for a test centre, providing that the teleworker has sufficient opportunities to interact with co-workers (by mail, telephone, messenger, teleconference, etc. and given a minimum of co-presence time).

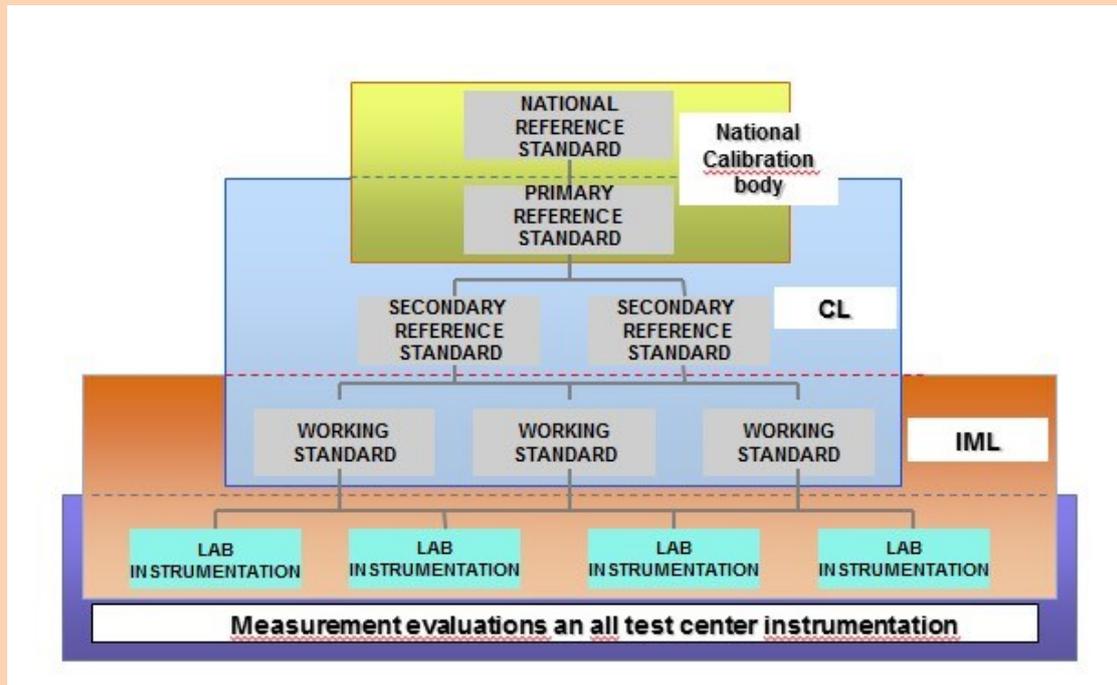
The effectiveness of the work done in tele-working can be evaluated by objectives, better than carefully controlling the working hours (however, tools exist also for that, for example, a virtual clocking in system).

9 Instrumentation maintenance and management

The maintenance and management of the quality and metrological characteristics of a test centre instrumentation for the correct testing process execution and for the support to quality systems for certification (ISO 9001:2000 and ISO/IEC 17025) are usually granted by two kinds of laboratories: the calibration laboratory and the instrumentation and management laboratory.

These laboratories, in order to provide a correct instrumentation management service, must operate according to the well know metrological chain described in Figure 15 representing the correct use of reference and working standards used by the different laboratories operating on instrumentation at different levels.

Figure 15: The metrological chain



Source: ITU

9.1 Calibration laboratory (CL)

The CL must be accredited by the national accreditation body for calibration (recognized by ILAC - International Laboratory Accreditation Cooperation), identified by a reference accreditation number and by a list of accredited quantities (for example: voltage, current, frequency, optical). For these quantities the calibration laboratory maintains the references standards for the instrumentations used by the test centre according to the national and international regulation on calibration.

9.2 Instrumentation and management laboratory (IML)

The IML usually offers internally the instrumentation management service in order to:

- perform periodical calibration;
- perform ordinary or extraordinary instrumentation maintenance;
- keep track of the maintenance and calibration history using *ad hoc* commercial application software.

More precisely, dedicated applications allow to keep under control the instrumentation registry (number of asset, vendor, model, serial number, installed options) and the history of operation executed on a single instrument (external or internal calibration, preventive or corrective, service, users, calibration documentation).

All documents needed (data tables, certificates, calibration tabs and technical procedures) are stored in a digital format on a protected server (read only) used by all company personnel. The IML personnel is responsible for the maintenance of the internal procedures finalized to protect all registrations saved in the information system (antivirus installation, back up, access priority control).

9.3 Instrumentation under quality system control

All instrumentation under quality control system must be listed in the company quality control system and identified with a “quality code” corresponding to a special sticker. A specific coding identifies the instrumentation category:

1. reference standards;
2. working standards;
3. instrumentation object of calibration;
4. auxiliary instrumentation.

This classification is done according to the metrological characteristics of the instrumentation (accuracy) and identifies the subsequent calibration activities.

Reference instrumentation must be sent to the external calibration centre, recognized by the national or international accreditation body, or to primary metrological centres while all other instruments can be calibrated using instrumentation with superior metrological characteristics (according to the metrological chain process).

Periodical calibration is managed by the information system, previously described; when the calibration date is expiring the system warns that the instrumentation must be calibrated and the expert from IML will start the formal procedure by informing the user that the process is starting.

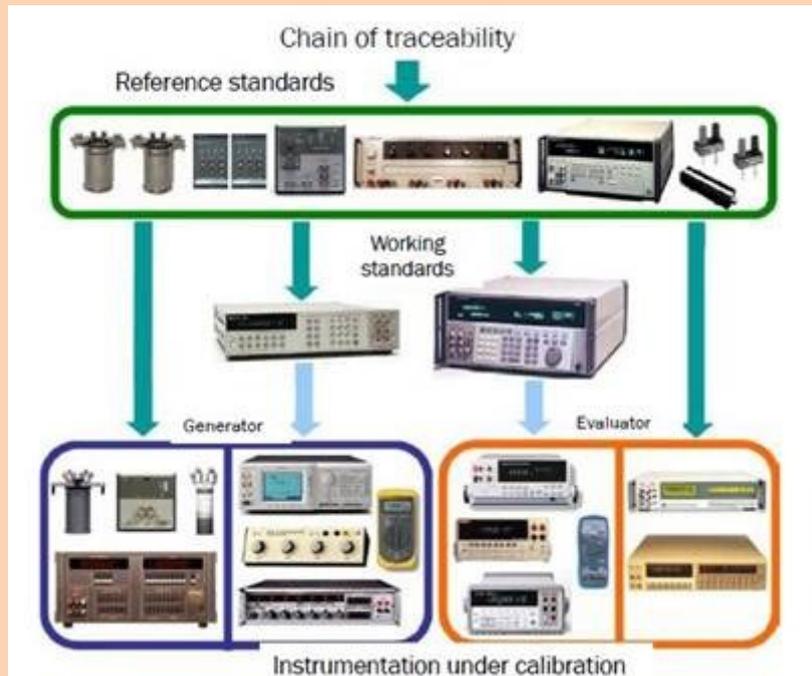
When the calibration can be managed internally the instrument will be executed by the IML personnel following the proper procedure (available on the dedicated server).

The technical procedure is the formal document identifying uniquely the instrumentation calibration process, it contains:

- the scope;
- application field;
- reference standards;
- auxiliary instrumentation;
- operational steps (including measurement set up);
- data tables to collect results (including measurement uncertainty).

The procedure must be approved by the IML responsible person (expert) before being used and enclosed in the dedicated list of formal laboratory document.

Figure 16: Chain of traceability



Source: ITU

The CL and IML housing must have controlled access and suitable environmental conditions in order to guarantee the necessary quality requirements. The environmental parameters (temperature and humidity) must be recorded and monitored according to the reference condition in order not to compromise the measurements results.

In some cases, it is necessary for an external calibration, for example when the instrumentation is a reference standard or there are no sufficient skills, in this case the CL will identify a suitable calibration centre according to the measurement requirements.

When the calibration is successfully carried out (either internally or externally) the results will be recorded on the informative system (calibration date, expiring date, name of the operator, standards used or calibration certificate emitted) and a special sticker is applied on the instrument with the calibration expiring date.

In some cases the calibration can be executed using automatic procedures developed using commercial software (HP VEE or NATIONAL laboratory view, for example). This kind of automatic procedure must be validated in advance using alternative methods in order to guarantee the correct execution in all phases. A possible approach is to use a manual method for the validation itself.

The results of the validation procedure must be stored on the informative system and executed again every time a change occurs.

A similar procedure must be adopted for repairing activities used if instrumentation fails. Also in this case the repairing process, that can be performed internally or externally, and all relevant information must be stored on the informative system (repairing date, fault description, replaced parts, repairing costs, necessity of a new calibration).

10 Quality aspect (UNI CEI EN ISO/IEC 17025)

For a test centre the quality is a decisive factor in the development of itself and the improvement of the services provided to clients. For this reason, all staff shall be aware of the importance of quality and put it into effect at all times.

The policy of a test centre in relation to quality is to achieve and maintain a high level of quality in all aspects of conformance testing services offered. A testing centre should provide its clients at all times with a service complying with the ISO/IEC 17025 accreditation standard for all tests for which it holds accreditation and must guarantee its impartiality and confidentiality as a third-party provider of conformance testing services.

It is the responsibility of all staff of a test centre to familiarize themselves with the content of this standard and comply with the policies and procedures laid down in the quality manual and associated documentation at all times.

In order to achieve and maintain a high standard of quality for implementing this quality policy, it is fundamental that the laboratory technical manager has the overall responsibility for managing the test services and for implementing the quality system in the laboratory. Moreover the quality manager must have the overall responsibility for the maintenance and control of quality and for advising on and monitoring all aspects of quality in the laboratory.

On a yearly basis, the quality manager must prepare a quality plan, and submits it to the quality steering group for approval. The quality steering group consists of the general manager, technical manager and quality manager. This quality plan shall indicate the objectives and the means to be used to obtain them. Verification that the objectives of the quality plan and the quality system have been reached shall take place annually through the quality system review meeting. Achieving quality objectives is in any case the joint responsibility of all personnel involved in the activities defined in the quality plan.

It is a policy of the management of the test centre to ensure that in the quality manual and in the related quality procedures all the potential problem of conflict of interest are taken into account and overcome, in order to guarantee to all clients that the independence of staff is maintained in all phases of their work.

The aim of a test centre quality system is:

- to ensure the quality policy is enforced at all times;
- to achieve and maintain a high level of quality in all aspects of conformance testing services;
- to ensure that the test services provided to clients comply with the national/international accreditation standard at all times for all tests for which they hold accreditation;
- to ensure that the quality requirements of clients are fully met on a continuing basis;
- to ensure the impartiality and confidentiality in all activities.

The quality system is formalized in the quality manual that describes:

- the quality system established by test centre to enable staff to operate in conformance to the reference standards;
- the test centre organization and the associated distribution of responsibilities;
- the technical setting in which conformance testing services are offered;
- general criteria for quality control and technical procedures.

10.1 Quality manual

The quality policies of a test centre are described in the quality manual that is an official document describing how the quality system operates. A typical quality manual will include the company quality policy and goals, as well as a detailed description of its quality control system that might include staff roles and relationships, procedures, systems and any other resources that relate to producing high quality goods or services.

The quality manager is responsible for authorization and compilation of the quality manual. The responsibility for editing and distributing of this manual rests with the secretary.

This quality manual must be distributed to all test centre staff.

This quality manual usually consists of the following parts:

- **Summary:** describes the index, the revision list of the general part and the annexes, the list of testing area and the accreditation status;
- **General part:** describes the quality system used, the responsibilities of test centre organization, the general criteria and references to quality control procedures;
- **Technical area annexes:** describe the environment, test systems, reference standards and technical procedures related to each of test centre testing areas.

10.2 Quality management

The technical manager is responsible for the management of the test services, for all aspects and results of the test centre testing activities and for the implementation of the quality system within the laboratory.

The quality manager is responsible for establishing and verifying the adequacy of the quality system described in this manual, monitoring all aspects of quality within the testing services and advising the technical manager and general manager accordingly.

10.3 Documentation

The documentation related to the quality system of the test centre includes:

- quality manual;
- quality control procedures;
- technical documents.

The quality control procedures define the ways to perform activities in order to achieve the objective of the quality control. The procedures that must be implemented in a quality manual are listed below:

- preparation and Implementation of test centre quality procedures;
- updating and distribution of quality manual;
- quality audit and review;
- appointment and training of personnel;
- test campaign management;
- control and updating of technical documentation;
- management of archives;
- security of computer software.

Responsibility for authorizing issue and updating of procedures falls to the quality manager, who checks the compatibility of the procedure with the quality system, and technical manager, for its endorsement in the test centre.

The technical documents are those documents related to the technical aspects of testing services. The responsibility for the control of technical documents rests with the testing area responsible concerned. Control and updating of the technical documents is covered by quality control procedure. All the information related to the technical documents is given in the technical area annexes of the quality manual.

Each member of test centre staff must have a controlled copy of the quality control procedures. Access to all other documentation, necessary for carrying out the conformance testing, is readily available to laboratory staff. The policy and procedures defined in the quality manual and any relevant quality control procedure must be studied carefully and enforced at any times by all centre staff.

10.4 Departure from documented procedures

Departures from quality control procedures or conformance testing specifications may be permitted during the day-to-day activity of test centre. In order to insure that the level of the quality system established is not set at risk the following procedure shall be followed:

- Any departure shall immediately be reported to the testing area responsible for technical departures and to the quality manager for quality control departures, by the personnel concerned, and documented.
- The personnel involved shall fill the departure from procedures form to describe the cause of the departure.
- If the departure is affecting the conformance test, the test must be stopped immediately.
- An investigation has to be carried out by the testing area responsible, to decide the action(s) to be taken. If there is any possibility that the integrity of the work will be affected, then the testing shall be re-started from the beginning and re-executed following the documented procedure. If it is determined that there are valid technical reasons for doing so and that the quality of the testing is not thereby set at risk, then testing can continue. However, the justification for it shall be documented in the DFP form (departure from procedures).
- Any decision and actions taken have to be reported in the DFP form.
- The DFP form shall be sent to the quality manager for reviewing and it is filed in the test campaign folder.

The DFP form is also used to document the issue of a new version or an amendment of test reports.

Departure could lead to take corrective actions. In this case the corrective action request form has to be completed.

Appendix A: Testing Laboratories and test plant infrastructure

Section	Testing laboratory acronym	Area of competence
A	SAR	Specific Absorption Rate lab
B	USX	User experience lab
C	BBA	Broadband access lab
D	VAS	Mobile value added services lab
E	EPS	Electrical safety & protection lab
F	ELA	Electroacoustic lab
G	EMC	Electromagnetic compatibility lab
H	RSL	Radio & Signalling lab
I	PWE	Powering efficiency lab
J	QML	Quality of material lab
K	WIF	Personal area network lab
L	TPF	Fixed Test plant
L	TPM	Mobile Test plant

A Specific absorption rate laboratory (SAR)

Scope of the laboratory

Various national regulatory agencies, for example the Federal Communications Commission (FCC) in the US, require the peak spatial-average SAR of wireless handsets to be evaluated to ensure compliance with their rules (Code of Federal Regulations and guidelines of the FCC). The SAR (Specific Absorption Rate, [W/kg]) values adopted by different countries are usually based on standards such as IEEE Standard C95.1 or guidelines such as those developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The SAR in a biological body exposed to an RF field, which quantify the power absorbed by a tissue per unit mass, depends on a number of factors, including tissue geometry and dielectric properties and the orientation of the body relative to the source. Since the RF energy induced in the body is scattered and absorbed at various tissue interfaces, the internal field and hence the SAR distribution is non-uniform. Energy coupling is complicated even further by source geometry and mutual coupling when the exposure is in the near field, e.g., exposure conditions associated with handheld radio transceivers. Evaluating the SAR distributions associated with such devices is a complex task, usually accomplished by measurement techniques or numerical modelling. One way to evaluate compliance with specific SAR requirements is by measurement of the electric field strength in a tissue-equivalent liquid using anthropomorphic models of the human head. The scope of the laboratory is to perform SAR measurement on handheld or wireless RF devices used in close proximity to the ear or the human body.

The current state-of-the-art regarding SAR assessment utilizes anthropomorphic-shaped phantoms made of a low-permittivity, low-loss plastic or fiberglass shell filled with homogeneous tissue-equivalent liquid. The phantom size and shape and the dielectric properties of the tissue-equivalent liquid used to represent average “head” tissue are chosen so that the measured SAR values are conservative, i.e., consistently exhibit a slight overestimation compared with heterogeneous anatomical head models.

While temperature-increase measurements using temperature probe or infrared camera techniques have been widely used in research or for transfer calibrations, these methods are not suitable for testing low-power devices because of their limited sensitivity and dynamic range. Only miniature E-field probes with

diode-loaded dipole sensors can provide the required dynamic range, and therefore, the handset test procedures described in this recommended practice are limited to measurement techniques using miniature E-field probes. SAR measurements are carried out by scanning within a thin anatomically based phantom shell filled with a tissue-equivalent liquid, typically using a multi-axis robot to position a miniature E-field probe. Once the regions of highest SAR are identified, post-processing algorithms subject to the requirements described in this document shall be used to average the local SAR over a prescribed volume to determine the peak spatial-average SAR.

List of laboratory testing services

SARLEV – determination of the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 850 MHz to 2 GHz).

BODYSARLEV – determination of the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 850 MHz to 2 GHz).

Reference standards

CENELEC EN50360/A1 – Product standard to demonstrate the compliance of mobile phones with the basic restrictions related to human exposure to electromagnetic fields (300 MHz – 3 GHz) [DOC.SARLEV.01], amendment; March 2012.

IEC 62209-1:2005 – Human Exposure to radio frequency fields from hand-held and body mounted wireless communication devices – Human models, instrumentation, and procedures- Part 1: Procedure to determine the Specific Absorption Rate (SAR) for hand-held devices used in close proximity of the ear (frequency range of 300 MHz to 3 GHz).

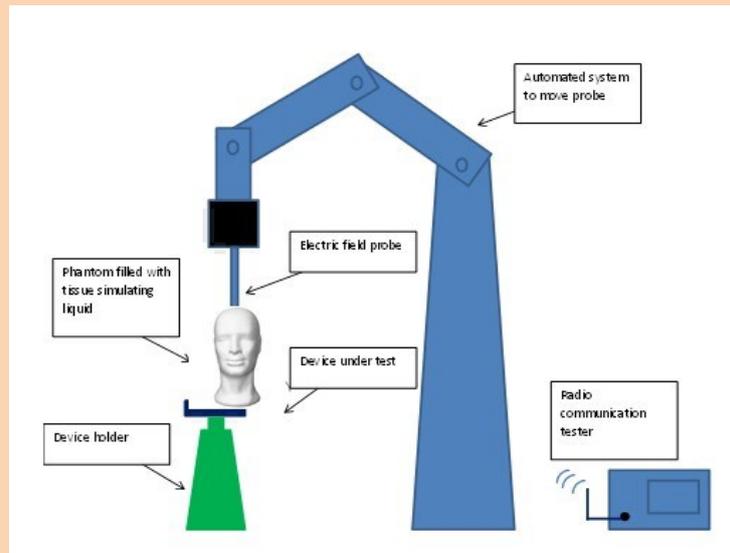
CENELEC EN 62209-1:2006 – Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz).

IEC 62209-2:2010 – Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz).

Test equipment set up and instrumentation

In this section the test equipment set up is described including the instrumentation list (main components). Additional instrumentation for measurement system verification or validation is included in the second table below.

Figure A1: SAR measurement system main components



Source: ITU

- ANTROPOMORPHIC ROBOT: 6-AXIS + CONTROLLER
- DEVICE HOLDER FOR HANDSET/WIRELESS DEVICES
- PHANTOMS (HEAD AND BODY)
- ELECTRIC FIELD PROBES
- DATA ACQUISITION ELECTRONICS/MEASUREMENT SERVER
- SAR MEASUREMENT SOFTWARE
- THERMOMETER, DATALOGGER
- VECTOR NETWORK ANALYZER
- DIELECTRIC PROBE KIT + SOFTWARE
- RADIO COMMUNICATION TESTER FOR DEVICE COMMUNICATION SETUP
- HYGRO-THERMOMETER
- CHEMICAL CABINET (STORE UP LIQUIDS)
- COMPUTERS, (PC/WORKSTATION/NOTEBOOK)
- SAFETY CURTAIN FOR ROBOTS

SAR measurement system validation/verification components (additional to previous table)

- FILTER, LOW PASS/HIGH PASS
- POWER METER
- POWER SENSOR, PEAK & AVERAGE
- POWER SENSOR, PEAK & AVERAGE
- COUPLER, DUAL DIRECTIONAL
- POWER SUPPLY
- RF AMPLIFIER

- RF ATTENUATORS
- RF GENERATOR
- PRECISION TERMINATION 50 OHM
- DIPOLE ANTENNAS
- FLEXIBLE MICROWAVE CABLES
- CIRCULATOR

Personnel competency matrix (main skills)

Laboratory manager: Electromagnetics, EMC, electronics, microwave and RF components, knowledge of mobile communication systems architecture and radio access techniques, strong knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: Electromagnetics, electronics, basic knowledge of mobile communication systems architecture and radio access techniques, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test campaign operator: Basic knowledge of physics recommended.

Technical experts (not mandatory, recommended): Physics, chemistry, mechanical engineering. Experts support laboratory manager and campaign responsible in head and body tissue liquids management as well as in laboratory hardware/robots management and installation.

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

Dimensions: Tests are recommended to be performed in a shielded environment:

- Distance between robot arm and chamber wall shall be ≥ 0.5 meter (typically one 3m * 4m room is enough for the operation of one single SAR measurement system).
- If absorbers are installed on the walls and on the ceiling, the distance between robot arm and wall has to be larger.
- Air conditioning is required in the chamber to maintain the temperature at the desired level. The robot arm and controller typically dissipate heat equivalent to 2 000 Watt
- Some tissue simulating liquids may have an unpleasant odour. Good ventilation or fresh air will improve the situation in the chamber.

Electrical requirements: The electrical outlet for the robot shall be within a range of 10 meters of the robot controller location and it shall be capable of providing the following amperage (typically):

- phases / 16 amps per phase if the voltage between two phases is 200 – 230VAC
- phases / 10 amps per phase if the voltage between two phases is 400 – 440VAC

If the robot controller is set up in a shielded room, it is recommended to use filters with the same rating to bring the electrical power into the shielded room.

Environmental requirements: The SAR measurement system works best in the following environment:

- temperature range: 18-25°C.
- humidity 20 – 90 per cent non-condensing.

For compliance measurements it is, however, required to set-up the measurement system in a controlled environment to maintain the liquid temperature with typical daily deviations of $\pm 1^\circ\text{C}$.

Robot stand: Typically robots are delivered with a robot stand. The robot is installed onto this stand. The robot stand has to be bolted to the floor in order to prevent the robot from falling. The construction of the floor shall be such that it can support the weight of the selected robot.

Safety: Safeguarding equipment must be installed and connected to prevent personnel entering the danger area (depending on the applicable safety distance from robot) during automatic operation. A light curtain shall be installed to be compliant with the European machinery directive or similar safety regulations.

- The respective curtain must switch off the system if it is interrupted.
- Emergency switches are located at the front panel of the robot controller, on the manual teach pendant of the robot and on the measurement system remote control unit. During operation, at least one of the switches must be within reach.
- Wiring and cabling shall not be exposed to chemical agents like the simulating liquids.
- Tissue simulating Liquids used with the system may be harmful and irritant. The manufacturer safety data sheets (MSDS) of the relevant components must be observed during manufacturing, handling, using, storage and disposal of the ingredients. The responsible operator has to take precautions that any personnel will not be harmed by the liquids, even when the system is not operated (e.g., outside of working hours). Harmful liquids shall be emptied from the system and stored correctly in their storage containers.

B User experience laboratory (USX)

Scope of the laboratory

To maximize the offer of innovative products and services, over the years it is necessary to realize a User Experience laboratory operating with close ties to the quality, marketing and engineering departments. This kind of laboratory must employ ergonomists who hold the European approved EUERG certification, psychologists and sociologists who are expert in communication and resource management and skilled in usability, ergonomics, user-centred planning, psycho-social research, psycho-metric statistics and communication. As well as designing user-centred new services and products like graphic interfaces and surfing procedures, this kind of laboratory arranges trials in systems, websites and products, qualitative analysis (focus group/brain storming), residential and business usability tests. It also prepares and manages online questionnaires and organizes recruiting for qualitative analyses. The laboratory must be equipped with residential and business office testing areas where our usability tests, videoconferences and focus group take place, and among its facilities there is a control room that manages and video records the activity of the test/focus room and the online questionnaire server.

List of laboratory testing services

QUALITATIVE SURVEYS on user needs and user requirements, for new products and services creation and development.

USABILITY TESTS with users in domestic and business contexts. The aim is to observe people using the product in Lab, to discover errors and areas of improvement

FOCUS GROUPS and BRAINSTORMING: Groups of people are asked about their attitude towards a product Design, Technology and Services. Questions are asked in an interactive group setting where participants are free to talk with other group members

TRIALS: Evaluate the customer experience in real context: from installation, configuration to software and hardware complete usage.

PRODUCT and SERVICE CONCEPTS: user-centred user interface, navigation flows and layout.

USABILITY HEURISTIC EVALUATION of WEB, IPTV interfaces of mobile, fixed and multimedia product and services. To evaluate critical aspects in terms of user experience related to GUI (graphical user interface), navigation paths and flows.

ONLINE SURVEYS, FORUMS and WEB DISCUSSIONS

RECRUITING of specific targets, based on internal database with 500 profiled users.

Reference standards

Usability definition ISO 9241 – 11, 1993

Test equipment set up and instrumentation

- user centred methods;
- test rooms, with both business and domestic furniture to conduct one-to-one usability tests;
- focus group and videoconference room;
- control room for audio and video monitoring and recording;
- internal database for user recruitment;
- server and client solution to publish online surveys;
- server and client solution to manage forums and web discussions.

Personnel competency matrix (main skills)

Laboratory manager: Psychologist, Sociologist, Communication Scientist, Audio-video Expert.

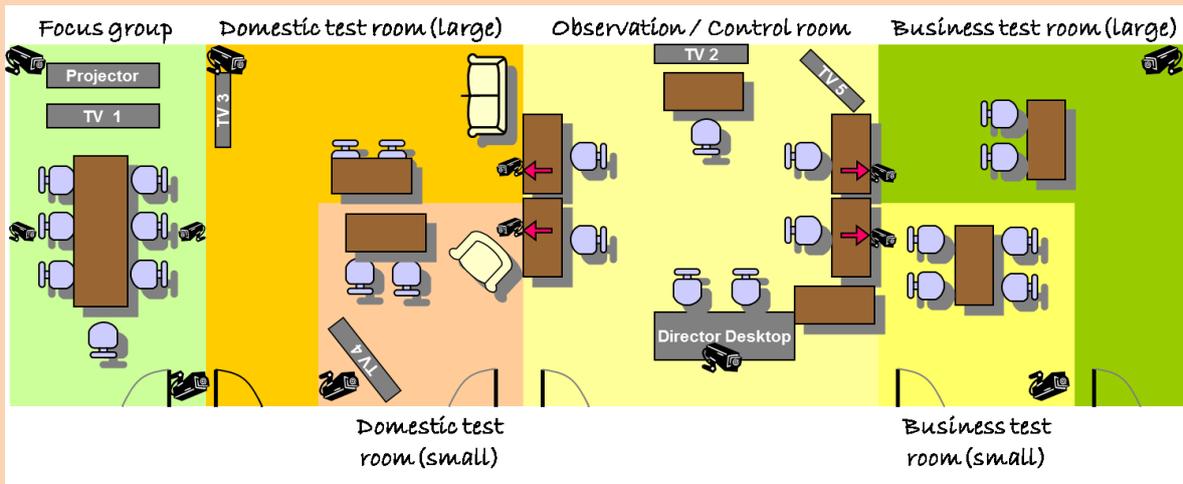
Test campaign responsible: Ergonomist, psychologist and sociologist who is expert in communication and resource management and skilled in usability, ergonomics, user-centred planning, psycho-social research, psycho-metric statistics and communication.

Test campaign operator: Basic knowledge of usability, communications and main technologies of the products and services to test.

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

Figure B1: Usability laboratory lay out



Usability laboratory



Source: ITU

C Broadband access laboratory (BBA)

Scope of the laboratory

The scope of the broadband access laboratory is to evaluate all different equipment and functionalities used in next generation access networks, ranging from the physical layer to networking aspects. In particular xDSL transmission performances and optical parameters are tested for copper and fibre solution in relation to the different architectural choices (FTTB, FTTCab, FTTH, FTTE).

List of testing services

xDSL physical layer test: These tests are specified for functional and performance interoperability of the system under test (ADSL1, ADSL2+, SDSL, VDSL) against reference implementation. These tests are conceived in a way that they can also be used for the assessment of the interoperability, functionalities and performances of commercial equipment and reference designs (RD) for scouting and benchmarking of marketplace technologies.

GPON optical layer test: These tests are specified for functional and performance interoperability of the system under test (GPON interface) against reference implementation.

L2/L3 Functional Test: These tests mainly concern the verification of the correspondence of the service model implementation in the broadband access network equipment in the context of FTTE, FTTCab, FTTB, FTTH.

Reference standards

ITU-T G.992.5 “Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus)” (2009)

ETSI TS 101 388 V1.3.1 “Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements” (2002-05)

Broadband Forum (BBF) TR-100 “ADSL2/ADSL2plus Performance Test Plan” (2007-03)

Broadband Forum (BBF) TR-105 “ADSL2/ADSL2plus Functionality Test Plan” (2010-02)

Broadband Forum (BBF) TR-165 “Vector of Profiles” (2009-03)

ITU-T G.993.2 “Very high speed digital subscriber line transceivers 2 (VDSL2)” (2011)

ETSI TS 101 271 “Access Terminals Transmission and Multiplexing (TM); Access transmission system on metallic pairs; Very High Speed digital subscriber line system (VDSL2); [ITU Specification G993.2, modified] (2008-11)

Broadband Forum TR-114 “VDSL2 Performance Test Plan”, Issue 1 (2009-11) and corrigenda

Broadband Forum WT-114 Rev-13 “VDSL2 Performance Test Plan”, Issue 2 (2011-10)

Broadband Forum TR-115 “VDSL2 Functionality Test Plan”, Issue 1 (2009-11) and corrigendum

Broadband Forum WT-115 Rev-10 “VDSL2 Functionality Test Plan”, Issue 2 (2011-11)

Broadband Forum Technical Report TR-252 (2010-11)

Broadband Forum WT-252 Rev-03 (2011-12)

ITU-T Recommendation G.984-x Series Gigabit-capable Passive Optical Networks (GPON)

FSAN GPON OLT – ONU Interoperability Test Plan Working Text- Version 1.0

Broadband Forum TR-101 Technical Report “Migration to Ethernet-Based DSL Aggregation”

Test equipment set up and instrumentation

In this section are listed the main test instruments used for different test set-up.

- L2/L3 functional tests: ETH/IP traffic analyser/generator with main protocol emulation software licenses.
- GPON optical tests: optical power meter, variable optical attenuator, ETH/IP traffic analyser/generator with main protocol emulation software licenses.
- XDSL physical layer test: differential probe, loop simulator, noise generator, spectrum analyser, level meter, L2 traffic analyser/generator.

Personnel competency matrix (main skills)

Laboratory manager: xDSL and GPON transmission systems architecture, wired communication systems architecture and wired access techniques network, home network system architecture, cabling specification, knowledge of main foreign languages, knowledge of quality aspects.

Test campaign responsible: xDSL and GPON transmission systems architecture, wired communication systems architecture and wired access techniques network, home network system architecture, cabling specification, basic knowledge of quality aspects, skill in training and coordination of test campaign.

Test campaign operator: basic knowledge of xDSL transmission systems and Ethernet and IP protocols fundamental.

On-site requirements

There are not specific environment requirements for performing the tests above.

D Value added service laboratory (VAS)

Scope of the laboratory

This kind of laboratory checks mobile terminals for the fair performance of value added services (VAS) which are delivered by a mobile operator. VAS, also known as premium mobile services, typically concern in their basic version the download of operator logos, wallpapers, ringtones, video tones, screensavers, games, apps, chat and social networks, news and infotainment, mass voting services, etc.

The most recent development of their digital distribution concern some platforms which are commonly known as application stores (sometimes also referred to as an app store, app marketplace, or variations) often provided as a component of an operating system on a personal computer, smartphone, or tablet. Most application stores are curated and regulated by their owners (e.g. mobile terminals manufacturers), requiring that submissions go through an approval process where applications are inspected for compliance with certain guidelines (such as those for quality, content and billing), and also require that a commission be collected on each sale of a paid application. Some applications are developed by the mobile operator, due to their strategic relevance to the core business, and minor application stores are nevertheless in charge of the mobile operator; in this case the approval process may be conducted by the VAS laboratory.

List of testing services

New terminal acceptance: After a new mobile terminal has passed both the conformance and the supplementary testing procedures related to the radio, signalling, SAR, IOT, etc. components it's useful to check that a predefined subset of applications chosen among the most used or the most profitable ones for a mobile operator still works properly on the new terminal; subsequent h/w and s/w releases of the mobile terminal will be tested again only in these areas which are affected by a change, as declared from the mobile terminal manufacturer.

New application acceptance: After a new application has passed all the tests related to system and integration of different s/w components on a specific mobile terminal it's useful to check that this new application is effectively compatible with a predefined subset of mobile terminals chosen among the most used or the most recent ones for a mobile operator; subsequent s/w releases of the application will be tested again only in these areas which are affected by a change, as declared from the application manufacturer.

Monitoring of VAS services: Periodic evaluation of value-added services (VAS) quality monitoring policies within the domestic network. Some possible examples of these activities include:

- Statistical evaluation (both manual and automatic, on a day-per-day basis) of access time and completeness/correctness of most used mobile URLs (e.g. mobile operator home page, over-the-top applications home and login page, etc.).
- Benchmarks of aforementioned statistics for different mobile network operators.
- Residual failure rates for applications available in mobile operator application stores, with reference to the different phases of purchasing phases.
- Compliance with guidelines related to quality of VAS services as perceived by the end user (e.g. transparency in communication, usability of services, accessibility).

Reference standards

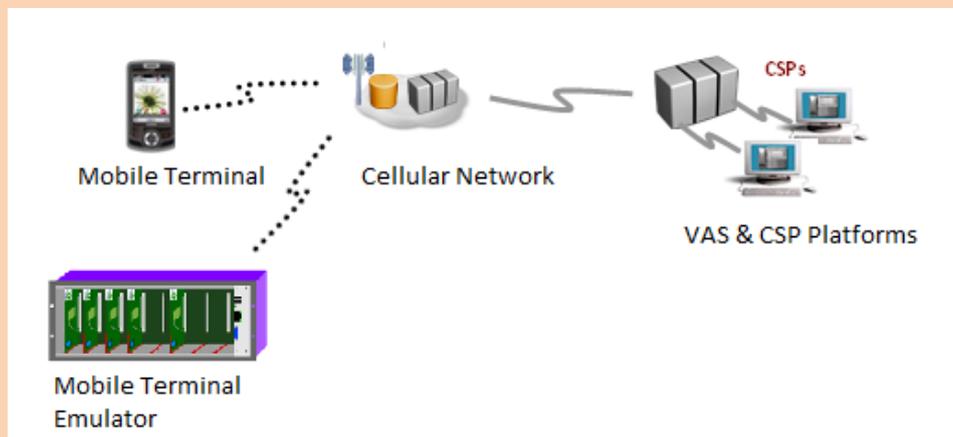
Due to the fact that many testing activities are strictly the consequence of a mobile operator specific strategy in the deployment of new terminals/services, most reference documents are operator dependent. Nevertheless this area is accredited by the Italian National Accreditation Body to show conformity of activation, usage and deactivation of subscription mobile VAS, according to the following reference standard:

CASP – Italian Code of Conduct for the offer of premium SMS/MMS services – version 2.0 – 16/11/2009, recently agreed by most Italian mobile operators and content service providers.

Test equipment set-up and instrumentation

In this section the test equipment set-up is described, including the instrumentation list (main components). Additional instrumentation for measurement system verification and for test collect platform is included in the second table below.

Figure D1: VAS laboratory main components



Source: ITU

- CERTIFIED/COMMERCIAL MOBILE TERMINALS from different Manufacturers
- COMMERCIAL SIMs from different Mobile Operators
- SIM PROFILE MANAGEMENT TOOLS
- COMMERCIAL S/W SUITES for interfacing a PC with a mobile terminal
- MOBILE TERMINAL EMULATOR for automatic testing
- SIM BILLING MANAGEMENT TOOLS
- TERMINAL TESTER for Coverage

VAS measurement system verification and test collect platform (additional to previous table).

- RADIO SCANNER for Coverage verification
- CONTENT MANAGEMENT SYSTEM for collecting test campaigns results
- CROWDTESTING PLATFORM

Personnel competency matrix (main skills)

Laboratory manager: good knowledge of VAS platforms architecture, of operating systems and user interface for mobile terminals, good knowledge of principles of s/w testing, basic knowledge of mobile

communication systems architecture and radio access techniques, deep knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), good knowledge of English recommended.

Test campaign responsible: good knowledge of VAS platforms architecture, of operating systems and user interface for mobile terminals, good knowledge of principles of s/w testing, basic knowledge of mobile communication systems architecture and radio access techniques.

Test campaign operator: basic knowledge of VAS platforms architecture, of operating systems and user interface for mobile terminals, basic knowledge of principles of s/w testing and of Mobile communication systems architecture and radio access techniques

Technical experts (not mandatory, recommended): Deep knowledge of VAS platforms architecture, of operating systems and usability of user interface for mobile terminals, deep knowledge of mobile communication systems architecture and radio access techniques, deep knowledge of related topics for ad-hoc insights, such as for example: billing, security, regulatory issues, new testing techniques (e.g. crowd-testing, teleworkers testing), DBMS.

On-site requirements

In the following some information related to the requirements of the laboratory are reported.

Coverage requirements

A good radio-electric coverage must be guaranteed during testing. For a quantitative evaluation of the radio coverage it is used a mobile terminal tester that detects – through a special application installed on it – the level of the radio electric signal during the test (of course that terminal must use a SIM of the same operator in relation to which it is decided to carry out the test). Measurements made by this application are periodically compared with a radio scanner, which acts as a measuring instrument of radio coverage and the related report of compliance is issued.

Environmental requirements

The environmental conditions of the laboratory which is used for testing are controlled and regulated by air conditioning and autonomous systems and comply with the requirements of the individual pieces of equipment used.

The environmental values of temperature and humidity of the laboratory do not, however, have influence to the typical VAS tests and are therefore not detected during the test campaigns.

VAS platforms availability

The availability of these platforms is to be checked especially when automatic testing is concerned, because a temporary lack in their availability and/or full operation can influence a proper interpretation of the test results. A direct link with the operations branch of the mobile operator is suggested, so that offline platforms times may be known in advance.

Safety

No particular safety requirements are requested apart from the general ones deriving from quality documentation as prescribed in reference standards ISO 9000 and ISO/IEC 17025.

E Electrical safety and protection laboratory (EPS)

Scope of the lab

The free movements of electrical equipment into the European market has brought to the harmonization of the laws of Member States. The result of such a harmonization is represented by the Low Voltage Directive 2006/95/EC that defines the general principles of safety recognized over the whole European Community.

For free circulation of the electrical products the Low Voltage Directive has defined as the only imperative provision for the compliance to the state-of-art recognized into Europe and consequently the compliance with harmonized safety standards.

The harmonized standards are those prepared by CENELEC and once published on the official Journal of European Community must be implemented at national level by all European countries. Most of European standard are however submitted to the IEC-CENELEC parallel vote in particular when the standard is prepared by an IEC Technical Committee; so it's possible to talk about a harmonization of safety technical requirements at international level.

In any case manufacturers shall understand the general principles behind the safety requirements in order to design safe equipment. In particular in designing equipment manufacturers shall guarantee the protection against hazards not only in normal operation conditions but also in a single fault condition that may have an impact into the addition of safety guards, metallic protection screens and so on.

Manufacturers shall also study the influence that external physical magnitudes may have on the product producing a reduction of safety levels as for example temperature, humidity, altitude, dust and, not less important, surges induced by lightning on mains and telecommunications lines that can produce insulation breakdowns.

Overvoltage and over currents induced by lightning, beside to safety issues, may produce also damages or unacceptable disoperation of equipment; to oppose these damages it's necessary that the manufacturer provides, during the design phase, adequate protection devices on PCB as solid state devices, varistors, gas discharge tubes. The damages produced by surges are increased in the last years due to the massive use of electronic equipment more sensitive respect to voltage variation over the intended rated voltage. Besides, the function of such equipment in many cases doesn't allow their out-of-order neither for short period of time.

Not only the common mode over voltages (over voltages respect to earth) but also those in transverse mode (over voltages between conductors) contribute to produce a damage into equipment. The level of over voltages induced by indirect lightning (the ones produced by a lightning cloud to cloud or a lightning nearby the building hosting the equipment) on external and internal interfaces are standardized by Recommendation of series K of ITU-T.

List of laboratory testing services

- Evaluation of safety requirements for information technology and telecommunication equipment.
- Evaluation of resistibility requirements for information technology and telecommunication equipment.

Reference standards

CENELEC EN 60950-1 – EN 60950-1/A11 "Information technology equipment: Safety Part1" [DOC.S/ITE.01].

CENELEC EN 60215 "Radio Transmitter Safety" [DOC.S/RT.01].

Recommendation ITU-T K21 – Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents [DOC.P/TE/01].

Recommendation ITU-T K20 – Resistibility of telecommunication equipment installed in a telecommunications centre to over voltages and over currents

Recommendation ITU-T K45 – Resistibility of telecommunication equipment installed in the access and trunk networks to over voltages and over currents.

Recommendation ITU-T K44 – Resistibility tests for telecommunication equipment exposed to over voltages and over currents – Basic Recommendation.

Test equipment set up and instrumentation

In this section the main test equipment to perform the test centre activities are listed:

- DIELECTRICMETER
- CONTINUITY EARTH METER
- PROBE, ARTIFICIAL FINGER
- PULSE GENERATORS
- POWER METER
- AC POWER SOURCE
- VOLTMETER, AMPERMETER
- TOUCH CURRENT NETWORK
- INSULATION TRANSFORMER
- OSCILLOSCOPE
- DROP
- HYGRO-THERMOMETER
- COMPUTERS, (PC/WORKSTATION/NOTEBOOK)
- CALIPER
- PROFILE PROJECTORS
- COUPLING NETWORK
- VOLTAGE SURGE GENERATOR UP TO 15kV
- CURRENT SURGE GENERATOR UP TO 20kA
- CURRENT PROBES
- HIGH VOLTAGE PROBES
- MATCHING NETWORK
- LOAD NETWORK
- ELECTRONIC LOADS

Figure E1: Example of safety and protection measurement instruments (included into previous list)



Source: ITU

Personnel competency matrix (main skills)

Laboratory manager: Equipment and plant safety, resistibility, protection electronics components knowledge, ICT network and systems architecture, strong knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: Electromagnetics, electronics, basic knowledge of mobile communication systems architecture and radio access techniques, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test campaign operator: Basic knowledge of safety and resistibility aspects recommended.

Technical experts (not mandatory, recommended): Physics, chemistry, mechanical engineering. Experts support laboratory manager and campaign responsible in head and body tissue liquids management as well as in laboratory hardware/robots management and installation.

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

Dimensions

Some tests are recommended to be performed in a shielded environment, for example the ESD tests required by ITU-T Recommendations.

- Distance between equipment and chamber wall shall be ≥ 1 meter (typically one 3m * 4m room is enough for the operation of one single measurement system).

Electrical requirements

The tests usually shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the following parameters:

- supply voltage (usually -10/+10%);
- supply frequency (usually -5/+5%);
- operating temperature (depends on what is declared by manufacturer);
- operating mode (depends on equipment)

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (d.c., AC mains supply frequency, high frequency

and harmonic content) of the parameter being measured. When the r.m.s. value have to be measured, care shall be taken that measuring instruments give true r.m.s. readings of non-sinusoidal waveforms as well as sinusoidal waveforms.

Environmental requirements

The safety measurement should be carried out in the following environment:

- temperature range: 18-25°C;
- humidity 20 – 90 per cent non-condensing;
- air pressure 860 ÷ 1060 hPa.

Safety

Usually safety and resistibility tests shall be performed only by skilled personnel. However equipment that generate high voltages shall be provided with safeguarding devices that must be activated to prevent personnel entering into contact with dangerous parts (depending on the applicable safety test) during measurement process. Usually a safeguard device like a traffic light is provided compliant with similar safety regulations.

F Electroacoustic laboratory (ELA)

Scope of laboratory

An electro acoustic laboratory typically tests telephometric characteristics of handset and hands free telephones. This kind of laboratory usually offers test services for electric characteristics of analogue terminal and FXS/FXO interfaces. The typical item under test are handset and hands free telephones, analogue interfaces of access gateway for xDSL access services and xDSL filters.

The main scope of this activity is test and consulting activity on terminals to guarantee the correct interworking with the network and to ensure a good audio quality.

List of testing services

The typical test services are:

- electroacoustic tests of hands free telephones;
- electroacoustic tests of mobile phones;
- electrical characteristics and transmission response of analogue interfaces (FXS)
- characterization of xDSL filters

Reference standards

Testing services are based on the following standards:

TBR8: ISDN; 3,1kHz telephony teleservice. Attachment requirements for handset terminals

TBR38: Public Switched Telephone Network (PSTN); “Attachment requirements for a terminal equipment incorporating an analogue handset function capable of supporting the justified case service when connected to the analogue interface of the PSTN in Europe”

ES 203021: Access and Terminals (AT); Harmonized basic attachment requirements for Terminals for connection to analogue interfaces of Telephone Networks; Update of technical contents of TBR021, EN301437, TBR015, TBR017

ETSI TS 126 131: Universal Mobile Telecommunications System (UMTS); LTE; Terminal acoustic characteristics for telephony; Requirements

ETSI TS 126 132: Universal Mobile Telecommunications System (UMTS); LTE; Speech and video telephony terminal acoustic test

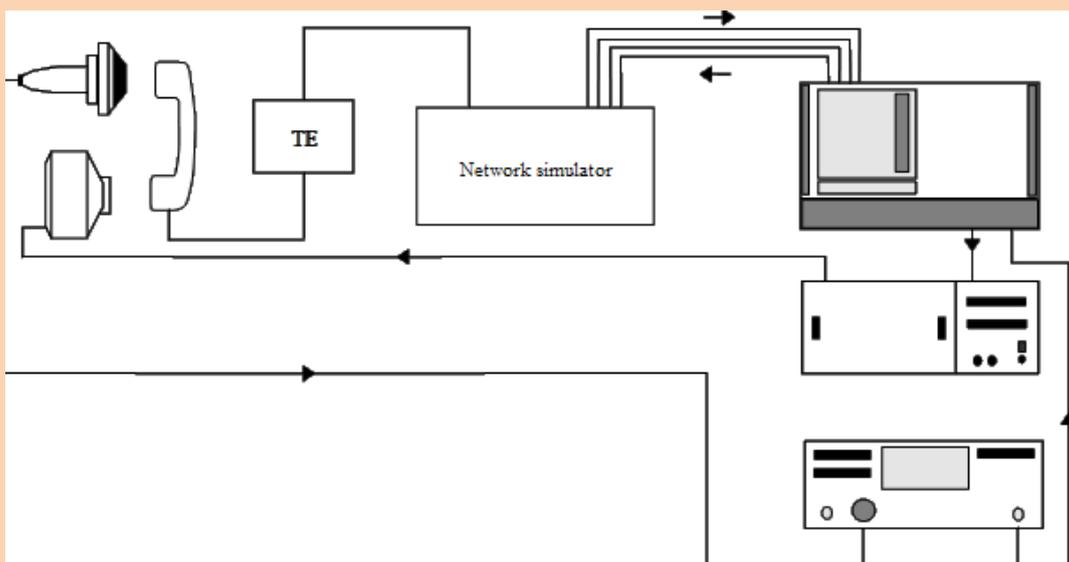
Test equipment set up and instrumentation

To ensure the correct interworking with the network and the analogue terminal (or telephone), performance requirements defined in the standard above have to be investigated. In particular following electroacoustic aspects are covered:

- loudness ratings;
- idle channel noise;
- sensitivity/frequency characteristics;
- sidetone loss;
- stability loss.

The test configuration employed is showed in Figure F1.

Figure F1: Test setup for interworking measurement



Source: ITU

Main components of measurement system are:

- anechoic room (opt);
- audio analyser;
- protocol analyser;
- telephone interface;
- mouth simulator;
- artificial ear;
- measurement microphones;
- pistonphone.

Personnel competency matrix (main skills)

Laboratory manager: Physics, electronics, quality aspects.

Test campaign responsible: Physics, electronics, quality aspects.

Test campaign operator: Basic knowledge of physics recommended.

On-site requirements

In the following some information related to the laboratory are reported.

Environmental requirements

Environmental conditions are conforming to all "general requirements" reported in the reference standards.

Background noise for electroacoustic tests is at most -64dBPa(A).

G EMC laboratory (EMC)

Scope of the laboratory

Electromagnetic compatibility (EMC) means the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment. Moreover the equipment must not be susceptible to having its operation affected by levels of electromagnetic energy typically present in its intended operating environment. The EMC testing is performed to determine whether the equipment is compatible with the electromagnetic environment in which is designed to operate.

The main objective of the Laboratory is to assess the compatibility of equipment (that is apparatus and fixed installations) regarding EMC. Usually the Apparatus are assessed by using testing and measurement methods which are addressed in the relevant EMC International Standard published by the international standardization body active in the field of Electromagnetic Compatibility (IEC, IEC/CISPR, ITU-T, ISO, CENELEC, ETSI). Tests can be applied to equipment for many reasons, for example:

- design tests during development;
- type tests (conformance tests);
- acceptance tests;
- production tests.

In order to control the interferences produced by apparatus various regional and national administration, for examples EU, USA, CANADA etc., have regulated the essential EMC requirements of the equipment based on the international standard. Meeting this technical standard is the obligation of the manufacturer or importer before to put equipment in to their internal market. Type testing (conformance testing) is testing to determine whether a product or system meets some specified standard that has been developed in order to demonstrate the conformance with a specific regulation.

The following aspects are generally considered in the EMC standards:

1. EMC phenomenon or emitted disturbance associated with:
 - conducted (continuous and intermittent) radiofrequency disturbance;
 - radiated radiofrequency disturbance.
2. Immunity phenomenon such as:
 - radiofrequency immunity;
 - electrostatic discharge (ESD);
 - surges;
 - burst/electrical fast transient;
 - harmonics, flicker voltage;
 - fluctuations.
3. Test procedures and requirements associated with the EMC phenomenon.

The EMC standards that handles all the above aspects are divided into the following categories.

1 Basic standards

Basic EMC Standards give the general and fundamental conditions or rules for the assessment of EMC and related performance of all products, systems or installations, and serve as reference documents for CISPR Generic and Product Standards. Basic Standards are general and hence are not dedicated to specific product families or products; they relate to general information, to the disturbing phenomena and to the measurement or testing techniques. They do not contain any prescribed limits or any product/system related performance specifications.

2 Generic standards

Generic EMC Standards are Standards related to a particular environment, which specify the minimum set of essential EMC requirements and test procedures, applicable to all the products or systems intended for operation in this environment, provided there do not exist any specific EMC Standards for a particular product family, product, system or installation. Limits are included, and reference is made to the test procedures.

3 Product standards

Product Standards define specific EM requirements, test procedures and limits dedicated to particular products, systems or installations for which specific conditions must be considered.

If there is an existing applicable generic standard, product family standard or a dedicated product standard, these standards have the following priority (see IEC Guide 107):

- dedicated product standard;
- product family standard;
- generic standard.

List of testing services

The focus of an independent EMC laboratory generally is on the type tests or conformance tests; This means that the testing service of the laboratory depend on the specific business environments and to a specific category/family of products (telecom, industrial, or residential apparatus etc.) and to the correlated EMC standard (product, family or generic standard) which defines the requirements that the product must meet before compliance is recognized. On the other hand the ISO/IEC 17025 states the competency of the laboratory and is based on test methods. These test methods can be called out in published international standards or can be internally developed. In the latter case the test methods must be validated for suitability and accuracy.

Reference standards

At the international level the Electromagnetic Compatibility testing and measurement techniques are addressed mainly by various Committee of International Electrotechnical Commission (IEC). The objective of the IEC is to promote international cooperation on standards in electrical and electronic field. In particular for the EMC aspects the basic standards for the Radio frequency emission phenomena are handled by IEC/CISPR while the basic standards for the immunity phenomena and are generally addressed by IEC SC 77A and IEC SC 77B committees.

List of available current CISPR standards

The main basic standard published by IEC/CISPR is the series CISPR 16 “Specification for radio disturbance and immunity measuring apparatus and methods” which is published in multiple parts and sub-parts:

Part 1: Specification for radio disturbance and immunity measuring apparatus and methods.

Part 2: Methods of measurement of disturbances and immunity.

Part 3: CISPR Technical Reports.

Part 4: Uncertainties, statistics and limit modelling.

CISPR basic EMC standards

CISPR 16-1-1 Part 1-1: Measuring apparatus

CISPR 16-1-2 Part 1-2: Ancillary equipment – Conducted disturbances

CISPR 16-1-3 Part 1-3: Ancillary equipment – Disturbance power

CISPR 16-1-4 Part 1-4: Antennas and test sites for radiated disturbance measurements

CISPR 16-1-5 Part 1-5: Antenna calibration test sites for 30 MHz to 1 000 MHz

CISPR 16-2-1 Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

CISPR 16-2-2 Part 2-2: Methods of measurement of disturbances and immunity – Measurement of disturbance power

CISPR 16-2-3 Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements

CISPR 16-2-4 Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements

CISPR 16-4-2 Part 4-2: Uncertainties, statistics and limit modeling – Uncertainty in EMC measurements

CISPR/IEC generic EMC standards

IEC 61000-6-3 Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments

IEC 61000-6-4 Part 6-4: Generic standards – Emission standard for industrial environments

IEC 61000-6-1 Part 6-1: Generic standards – Immunity for residential, commercial and light industrial environments

IEC 61000-6-2 Part 6-2: Generic standards – Immunity for industrial environments

CISPR product standards

CISPR 11 Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement

CISPR 12 Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of off board receivers

CISPR 13 Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement

CISPR 14-1 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission

CISPR 14-2 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 2: Immunity – Product family Standard

CISPR 15 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

CISPR 20 Sound and television broadcast receivers and associated equipment – Immunity characteristics – Limits and methods of measurement

CISPR 22 Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement

CISPR 24 Information technology equipment – Immunity characteristics – Limits and methods of measurement

CISPR 25 Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of onboard receivers

Partial List of IEC basic standard related to immunity testing and measurement techniques: IEC 61000-4 series

The IEC 61000-4 series covers testing and measuring techniques for electric and electronic equipment (apparatus and systems) in its electromagnetic environment.

IEC 61000-4-2, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test

IEC 61000-4-3, Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test

IEC 61000-4-4, Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test

IEC 61000-4-5, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-6, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields instrumentation, for power supply systems and equipment connected thereto

IEC 61000-4-8, Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test

IEC 61000-4-9, Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques – Pulse magnetic field immunity test

IEC 61000-4-10, Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test

IEC 61000-4-11, Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity test

IEC 61000-4-16, 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 immunity test. For example, the European telecommunications Standardization Institute development and publishes conformance standards for telecommunication equipment to pass the following tests

The selection of the tests to be applied to particular equipment depends on several factors, such as

- types of disturbances affecting the equipment;
- environmental conditions;
- required reliability and behaviour;
- equipment characteristics.

With regard to the variety of equipment and environmental conditions some regional standardization body are involved in the definition of specific Product or Family product standard.

In Europe the standardizations body ETSI and CENELEC have produced specific product EMC standard respectively in the field of Telecommunication and radio communication area and for electrotechnical part. Generally all standards issued by ETSI and CENELEC make reference to the above cited CISPR and IEC basic standard for the testing and measurement techniques.

List of ETSI EMC Standard for Radio e for Telecommunication equipment intended to be used within a public telecommunications network:

- **ETSI EN 300 386:** Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; Electromagnetic Compatibility (EMC) requirements.
- **ETSI EN 301 489:** Series of EMC standards for radio products.

The above standards provide in Europa the necessary EMC requirements to enables the manufactures to demonstrated compliance with the European regulation (EMC Directive 2004/108/EC and RTTE Directive 99/05/EC).

The EMC requirements for the information technology Equipment are defined in Europe by CENELEC and are based on IEC/ CISPR product standard:

- **CENELEC EN 55022 (CISPR22):** "Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement".
- **CENELEC EN 55024 (CISPR 24):** Information technology equipment – Immunity characteristics – Limits and methods of measurement.

Test equipment set up and instrumentation

Test equipment set up and environment suitability including the characteristics of the instrumentation list are described in the basic standard which gives the rules for the assessment of EMC and related performance of all products. Additional instrumentation for measurement system verification or validation might be involved in specific product standard. Here are exemplified some EMC tests set-up.

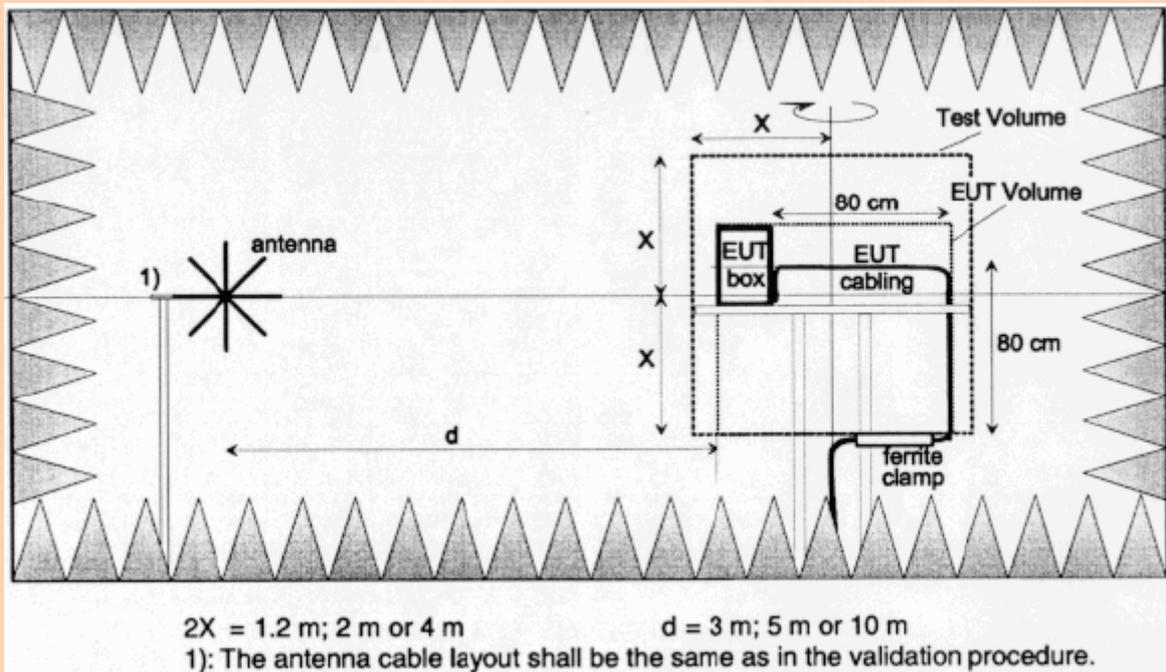
Test Site for radiated emission and radiated immunity measurements

Basic radiated emission measurement sites

The suitability of test sites for radiated emission test measurement test below 1 GHz are called out in the following standards: ANSI C63.4 for 47 CFR Part 15 and CISPR 16-2-3 for CISPR 11 and CISPR 22. The EMI measurements, for the evaluation of unintentional radiators, must be performed using a suitable test site

with a measurements distance of 3 or 10m, that can be either an Open Area Test Sites (OATS), an Semi Anechoic Chamber (SAC) or a Fully Absorber Lined Room (FAR). These sites shall meet, in the frequency range 30 MHz to 1 GHz, the Normalized Site Attenuation (NSA) criterion (of ± 4 dB), as defined in the CISPR 16-2-3 .

Figure G1: Typical set-up for table top equipment within a full anechoic room



Source: ITU

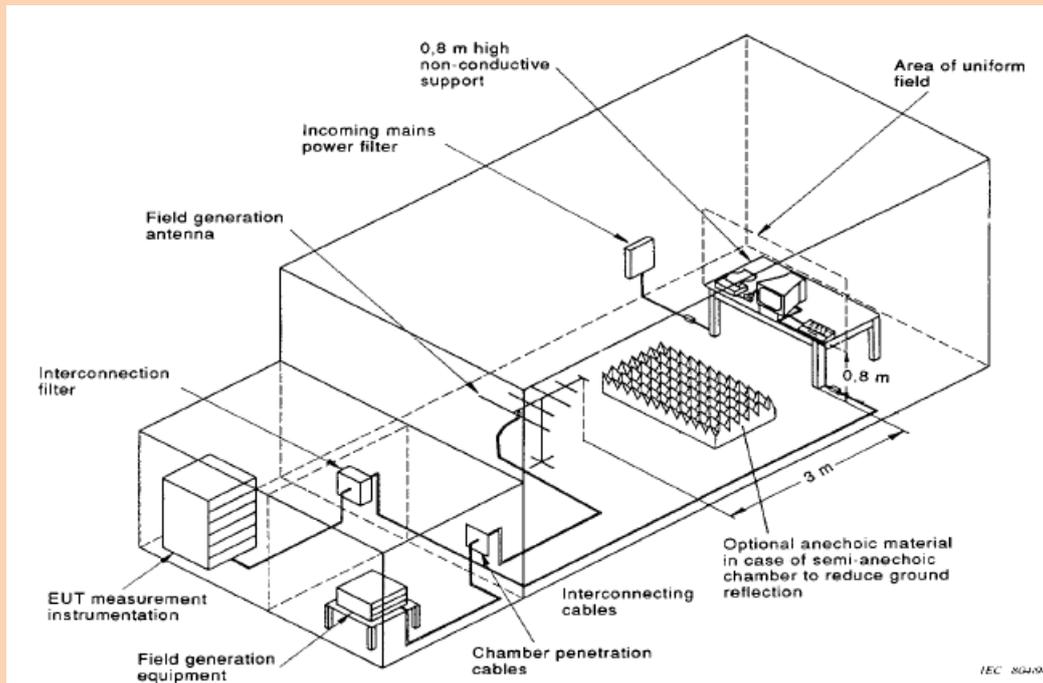
Site validation above 1 GHz normally uses site site-VSWR method, described in the CISPR 16-1-4, of comparing maximum deviations for several antenna positions using both antenna polarizations. To be acceptable the Site VSWR must be less than or equal to 6 dB.

Radiated Measurements test set-up shall require the use of equipment which are in compliance with the relevant basic standard. For measurements in accordance with standards based on CISPR standards (e.g., EN 55011 or EN 55022), they require the use of equipment which is in compliance with all requirements stated in CISPR 16-1-1. For examples at frequency below 1 GHz a specific EMI receiver is necessary because the spectrum analysers cannot be used for compliance testing, due to lack of compliance with CISPR 16-1-1. Above 1 GHz the use of spectrum analysers is permissible, as long as they meet all requirements called out in CISPR 16-1-1. In the CISPR 16-1-1 other limitation are defined for the supplementary instrumentation necessary to perform the emission measurements.

Radiated immunity testing

Radiated immunity testing not necessarily is reciprocal of radiated emission testing because it is necessary a proper field calibration technique that require a EMC chamber partially covered with pyramidal absorbing cones placed on the reflecting ground surface. The basic standard that defines the procedure of calibration is the IEC EN 61000-4-3. Test facility is needed to contain radiated RF energy and provide suitable test area. Primary specification of the test sites is uniform field area $-0/+6$ dB variation over 1.5×1.5 m plane located 0.8 m above floor. Up to 25 per cent of points is allowed to be out of tolerance. The calibration of uniformity is defined in the IEC EN 61000-4-3.

Figure 2: Typical set-up for table top equipment for radiated immunity tests



Source: ITU

Other conducted disturbances immunity testing

The IEC EN 61000-4-x standard addresses all the necessary reference to the conducted immunity testing for the various phenomena's including the test equipment.

Normally the IEC EN 61000-4-x standard provides the following general information:

- 1 Test equipment
 - test generator characteristics;
 - coupling devices;
 - decoupling devices.
- 2 Test set-up and coupling method of the disturbances
- 3 Test procedure
 - setting test generator;
 - applying disturbance to EUT;
 - evaluation of test results;
 - test report.

Personnel competency matrix (main skills)

Laboratory manager: EMC know-how. EMC knowledge test procedure defined in the international standard (IEC, CISPR, FCC etc.), knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: EMC Know-how, knowledge of EMC test procedure defined in the international standard (IEC, CISPR, FCC, etc.), telecommunication systems architecture and radio access techniques, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test campaign operator: Basic EMC knowledge is recommended, EMC knowledge test procedure defined in the international standard (IEC, CISPR, FCC, etc.);

Technical experts (not mandatory, recommended): Telecommunication network and systems architecture and telecom protocols and radio access techniques.

Sites requirements

In the following some information related to the physical layout of the laboratory are reported.

The radiated EMC tests (emission and immunity) require an open area test site (OATS) or a semi anechoic chamber (SAC) or a fully anechoic room (FAR) test site. The test distance shall be ≥ 3 metres (3 m, 5 m or 10 m). To reproduce the propagation conditions defined in the international standards, the wall, and the ceiling of the SAC shall be covered with anechoic material that could be absorbing pyramids and/or ferrite tile. In case of the FAR, in addition to the wall and the ceiling, the anechoic material shall be placed also on the floor.

For the measurement of radiated emission the test site shall be equipped with an antenna mast with height of 1-4 m and two polarizations and a turntable controlled externally to test room. The site needs to conform to the relevant characteristics defined in the CISPR standard (e.g. CISPR 22, CISPR 16-1-4 etc.)

For radiated immunity the test facility typically consists of an absorber-lined shielded enclosure large enough to accommodate the EUT whilst allowing adequate control over the field strengths. This includes anechoic chambers or modified semi-anechoic chambers. Associated shielded enclosures should accommodate the field generating and monitoring equipment, and the equipment which exercises the EUT.

All conducted (emission and immunity) tests are recommended to be performed in a shielded environment in order to confine the EM energy generated for the tests.

Electrical requirements

The electrical outlet shall be capable of providing the following amperage (typically):

- 16 amps per phase if the voltage between two phases is 200 – 230VAC;
- 30 amps per phase if the voltage between two phases is 400 – 440VAC;
- 42-56 Vdc, 20 A.

Environmental requirements

The EMC measurement system works best in the following environment:

- ambient temperature: 15 °C to 35 °C;
- relative humidity: 30 - 60 per cent;
- atmospheric pressure: 86 kPa (860 mbar) to 106 kPa (1 060 mbar).

H Radio and signalling laboratories (RSL)

Scope of the laboratory

Laboratories for carrier acceptance testing and for conformance testing are very similar because both verify the UE behaviour on the same standard interface; anyway operators have some specific requirements that cannot be verified by a standard body. Due to the complexity and the optionality of telecommunication system the conformance test cannot produce itself a testing coverage able to fulfil any commercial available implementation path. Therefore the operator testing complements the conformance testing which provide a baseline for the radio and signalling laboratories. International

standardization body for wireless networks and devices is 3GPP (3rd Generation Partnership Project) which is organized in four technical specification groups (TSG):

- radio access networks (RAN);
- service and systems aspects (SA);
- core network and terminals (CT); and
- GSM EDGE radio access networks (GERAN).

The 3GPP technologies from these groups are constantly evolving through subsequent generations of commercial cellular / mobile systems. Since the completion of the first LTE and the evolved packet core specifications, 3GPP has become the focal point for mobile systems beyond 3G.

Although these generations have become an adequate descriptor for the type of network under discussion, real progress on 3GPP standards is measured by the milestones achieved in particular 3GPP Releases. New features are 'functionality frozen' and are ready for implementation when a release is completed. 3GPP works on a number of releases in parallel, starting future work well in advance of the completion of the current release. Although this adds some complexity to the work of the groups, such a way of working ensures that progress is continuous and stable 3G systems should be based on new wide band, multimode, flexible radio access. This approach will ensure that systems based on 3GPP specifications will be capable of rapid development and deployment of competitive service offers while still enabling global roaming.

TSG- RAN (Technical specification group – radio access network) is responsible for the definition of the functions, requirements and interfaces of the UTRA/E-UTRA network in its two modes, FDD & TDD. More precisely: radio performance, physical layer, layer 2 and layer 3 RR specification in UTRAN/E-UTRAN; specification of the access network interfaces (Iu, Iub, Iur, S1 and X2); definition of the O&M (operation and maintenance) requirements in UTRAN/E-UTRAN and conformance testing for user equipment and base stations.

RAN WG5 (Working Group 5) is the group in charge of working on the specification for conformance testing at the radio interface (Uu) for the user equipment (UE). The test specifications are based on the requirements defined by other groups such as RAN WG4 for the radio test cases, and RAN WG2 and CT WG1 for the signalling and protocols test cases. RAN WG5 is organized in two subgroups, RF subgroup and signalling subgroup.

RADIO LAB

Scope of the laboratory

According to 3GPP RAN 5 RF subgroup indications and specifications, different environments and procedures have been developed in order to check and validate the correct behaviour of the UEs (User Equipment).

Two main typologies of tests are defined, conducted and OTA tests:

- **Conducted measurements** are carried out using a radio-frequency cable that connects the modem directly to the measuring bench. These measurements highlight the performance of the receiver and the transmitter, with the exclusion of the antenna. The measurements are made by connecting the UE's antenna connector to an instrument for measuring radio performance (radio communication tester) using a RF cable with known attenuation (static measurements).
- **OTA (over-the-air) measurements** are carried out in an anechoic shielded room, this simulates free space propagation. Before the measurements, the room must be calibrated for both polarizations in order to determine the overall attenuation between the test instrument's connector A and the location of the handset's antenna B.

This group of measurements shows the quality of the radio part of the UE (antenna and transceiver). The methodology used is aligned to the 3GPP TS.34.114 specification.

In this environment global radiated performances of UE are evaluated considering both OTA sensitivity and maximum transmitted power.

List of laboratory testing services

UE report: Purpose of this test is to check the values of the P-CPICH RSCP and P-CPICH Ec/No parameters measured by the UE and reported to the network, depending on the level of the signal received by the UE. CPICH RSCP is for handover evaluation, DL open loop power control, UL open loop power control and for the calculation of pathloss. CPICH Ec/No is for Cell selection/re-selection and for handover evaluation

Maximum output power

Aim of this measurement is to check the UE maximum transmitted power level. A too low transmitted power causes degradation in the quality of the mobile-base link and decreases the coverage area. A too high maximum output power can cause interferences to other users or other systems.

Minimum output power

Aim of this measurement is to check the UE's minimum transmitted power level. The minimum output power is defined as the mean power in one timeslot. An excess minimum output power increases the interference to other users, and can decrease the system capacity.

Uplink inner loop power control

Inner loop power control in the uplink is the ability of the UE transmitter to adjust its output power in accordance with one or more TPC commands received in the downlink. Control of the UE transmitted power is essential to ensure stable transmission and efficient radio resource management within the system. Generally speaking, an output power of the UE transmitter that is too low decreases the coverage area while an excess output power may cause interference to other users or systems. Both effects decrease the system capacity.

Static sensitivity measurement

Sensitivity indicates the radio receiver's ability to operate in difficult signal conditions. It is defined as the minimum level of the received power, at which the error probability limits defined in TS34.121 specifications, section 6.2, are respected. Aim of this measurement is to check the minimum power received at the UE antenna port at which the bit error ratio (BER) shall not exceed a specific value. The lack of the reception sensitivity decreases the coverage area at the far side from Node B.

Open loop power

Open loop power control in the uplink is the ability of the UE transmitter to set its output power to a specific value. The power measured by the UE of the received signal and the signalled BCCH information are used by the UE to control the power of the UE transmitted signal with the target to transmit at the lowest power acceptable for proper communication.

OTA sensitivity and maximum transmitted power

To check any loss of sensitivity not measurable with the conducted tests a measurement of the radiated static sensitivity on all the channels is carried out. Sensitivity measurements are performed with successive BER measurements, sending to UE a constant P-CPICH level of -70 dBm and finding the P-CPICH level at which the BER exceed 1 per cent

Reference standards

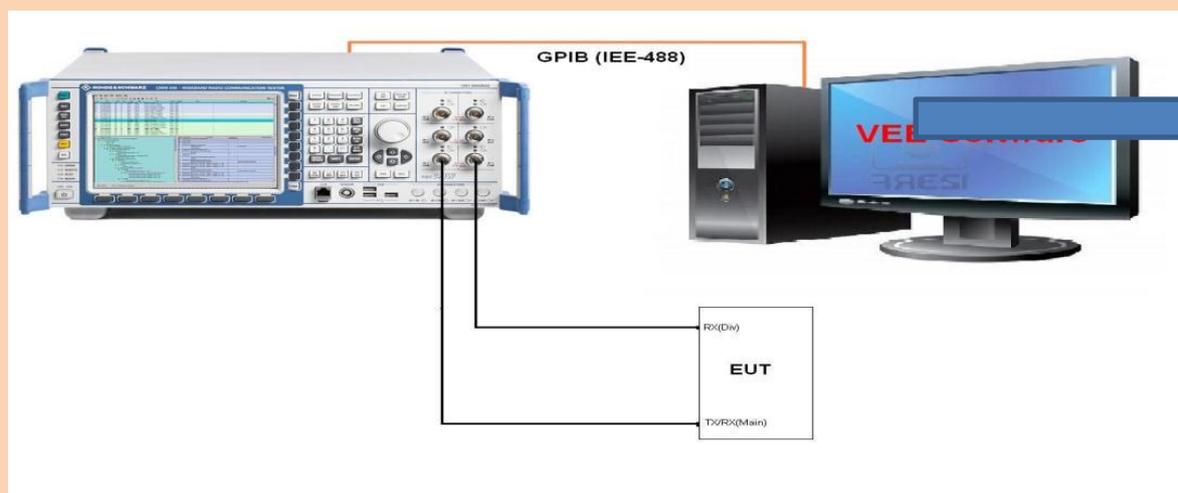
- 3GPP TS 34.121-1 Terminal conformance specification; Radio transmission and reception (FDD); Part 1: RF/RRM conformance testing.

- 3GPP TS 34.121-2 Terminal conformance specification; Radio transmission and reception (FDD); Part 2: Implementation Conformance Statement (ICS).
- 3GPP TS 34.114 User Equipment (UE) / Mobile Station (MS) Over The Air (OTA) antenna performance- Conformance testing.
- 3GPP TS 36.521-1 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 1: Conformance Testing.
- 3GPP TS 36.521-2 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 2: Implementation Conformance Statement (ICS).
- 3GPP TS 36.521-3 Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 3: Radio Resource Management Conformance Testing.

Test equipment set up and instrumentation

In this section the test equipment set up is described including the instrumentation list (main components).

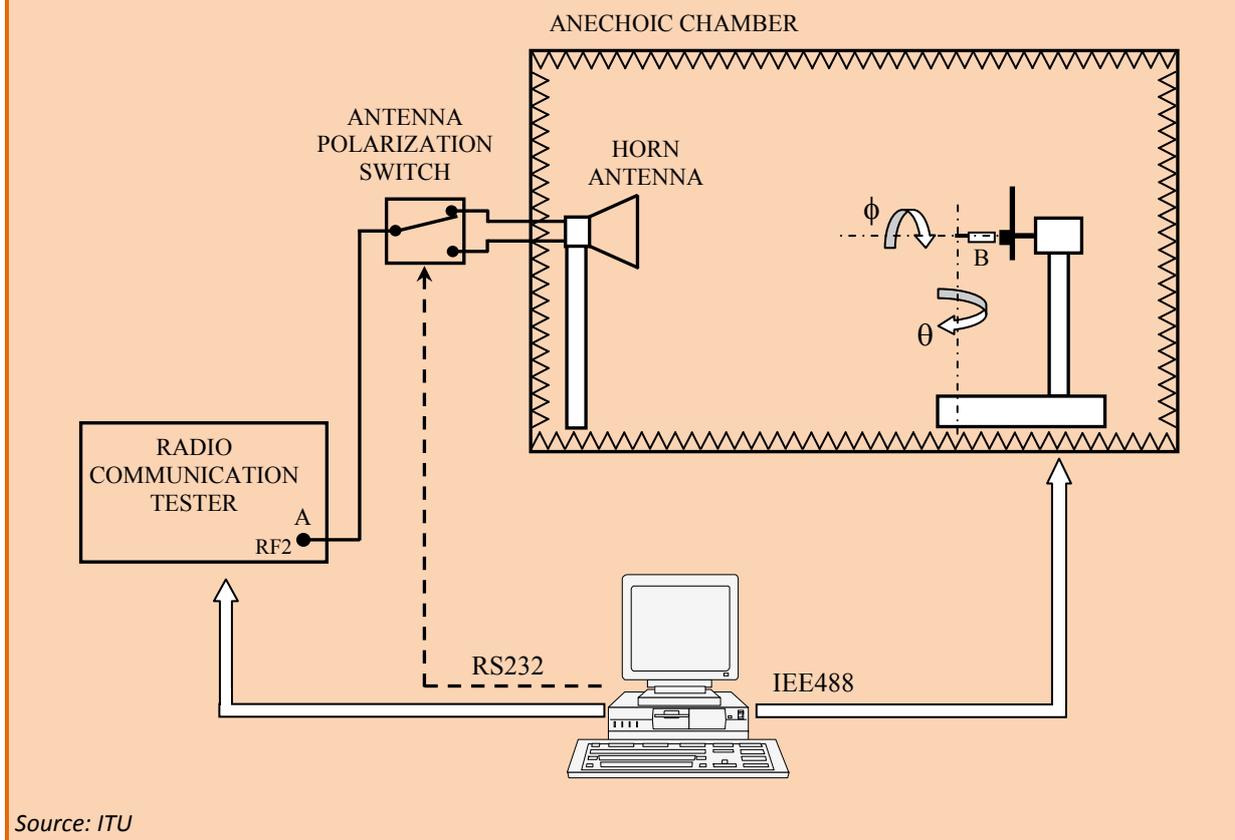
Figure H.1: Conducted measurement system main components



Source: ITU

- RADIO COMMUNICATION TESTER
- DEVICE HOLDER FOR HANDSET/WIRELESS DEVICES
- DATA ACQUISITION ELECTRONICS/MEASUREMENT SERVER
- COMPUTERS, (PC/WORKSTATION/NOTEBOOK)
- SHIELDED ANECHOIC CHAMBER
- RADIO COMMUNICATION TESTER
- MEASUREMENT ANTENNA
- TURNTABLE
- DATA ACQUISITION ELECTRONICS/MEASUREMENT SERVER
- COMPUTERS, (PC/WORKSTATION/NOTEBOOK)

Figure H.2: OTA measurement System main components



Source: ITU

Personnel competency matrix (main skills)

Laboratory manager: Electromagnetics, EMC, electronics, microwave and RF components, knowledge of mobile communication systems architecture and radio access techniques, strong knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: Electromagnetics, electronics, basic knowledge of mobile communication systems architecture and radio access techniques, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test campaign operator: Basic knowledge of physics recommended.

Technical experts (not mandatory, recommended): Strong knowledge in electromagnetics, EMC, electronics, microwave and RF components, knowledge of mobile communication systems architecture and radio access techniques

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

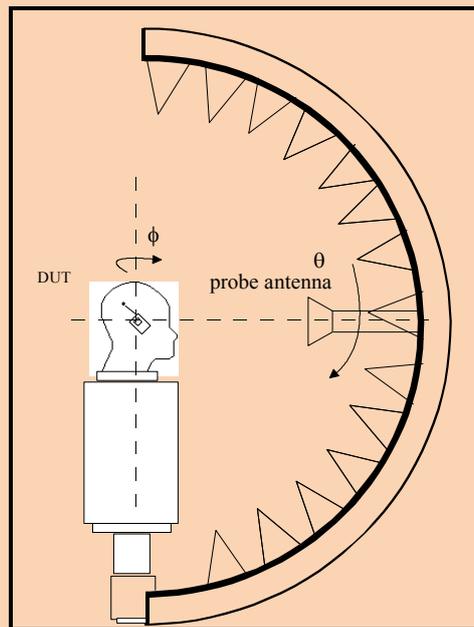
Anechoic chamber constraints

Testing shall be performed in an anechoic chamber fulfilling following requirements.

Positioner

The chamber should be equipped with a positioner making possible to perform full 3-D measurements for both Tx and Rx radiated performance. The centre of the rotation should be either right or left ear reference point of the SAM phantom. Alternatively centre of the line between right and left ear reference points can be used as a centre of rotation. Theta (θ) and phi (ϕ) angles are specified in Figure H.3.

Figure H.3: The coordinate system used in the measurements



Source: ITU

Measurement antenna

The measurement antenna should be able to measure two orthogonal polarizations (typically linear theta (θ) and phi (ϕ) polarizations). Note that single-polarized linear measurement antenna can also be used by turning it 90° for every measurement point.

For far-field measurements, the distance r between the DUT and the measurement antenna should be

$$r > \max\left(\frac{2D^2}{\lambda}, 3D, 3\lambda\right)$$

Where λ is the wavelength of the measurement frequency and D the maximum extension of the radiating structure. Then the phase- and amplitude uncertainty limits and the reactive near field limit are not exceeded. The distance r determines the anechoic chamber dimensions, 5x3x3 m are suggested in order to keep the DUT away from walls reducing the quiet zone reflectivity value.

Quiet zone

Reflectivity of the quiet zone must be measured for frequencies used. Measured reflectivity level is used in uncertainty calculations.

Shielding effectiveness of the chamber

The recommended level of the shielding effectiveness is -100 dB from 800 MHz to 4 GHz.

Electrical requirements

Standard power supply needed.

Signalling lab

Scope of the laboratory

According to 3GPP RAN 5 Signalling subgroup indications and specs, test procedures have been developed in order to check and validate the correct behaviour of the UEs (user equipment) vs. Radio Access Network.

Developed tests are not *conformance* tests, they are additional tests that aim to evaluate the quality of signalling procedures implemented by the UE, taking into account the execution time and reactivity of the UE itself.

List of laboratory testing services

Hereafter the list of 3G signalling tests executed in the lab:

Cell selection and cell reselection

- Cell Selection 3G
- Cell Selection 3G/2G
- Cell Reselection and recovery time 3G
- Cell Reselection and recovery time 3G/2G
- InterRAT recovery time when 3G cell became not available
- InterRAT reselection time when 3G cell became available

Location updating and registration

- Identity and Capability
- Periodic Location Updating in lack of coverage
- Location Updating Reject Inter Frequency condition
- Location Updating Equivalent PLMN
- Location Updating Reject and Emergency Call

Network selection

- Network Selection in International Roaming
- Network Selection from “Operator Controlled PLMN Selector with AT”
- Network Selection from “User Controlled PLMN Selector with AT”
- Periodic HPLMN searching when in International Roaming
- Steering of Roaming Cause#11 (PLMN not allowed)
- Steering of Roaming Cause#17 (Network Failure)

Measurement report

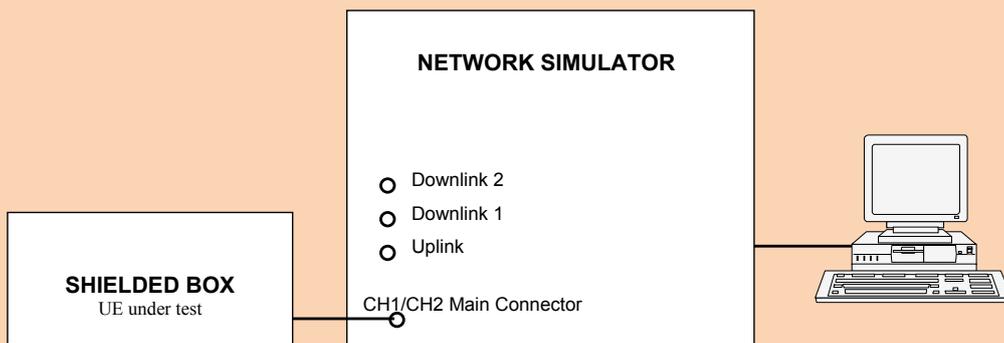
- Measurement Report 3G
- Measurement Report 2G/3G (InterRAT HO 2G/3G)
- Packet Switched
- Attach
- PDP Context - PDP Context Reject

Reference standards

- 3GPP TS 34.108 Common Test Environments for User Equipment (UE) Conformance Testing.
- 3GPP TS 36.508 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); Common test environments for User Equipment (UE) conformance testing.
- 3GPP TS 34.123-1 User Equipment (UE) Conformance Specification; Part 1: Protocol Conformance Specification.
- 3GPP TS 34.123-2 User Equipment (UE) Conformance Specification, Part 2 – Implementation Conformance Statement (ICS) proforma specification.
- 3GPP TS 36.523-1 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 1: Protocol conformance specification.
- 3GPP TS 36.523-2 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Packet Core (EPC); User Equipment (UE) conformance specification; Part 2: Implementation Conformance Statement (ICS) proforma specification.

Test equipment set up and instrumentation

Figure H.4: Test equipment set up and instrumentation



Source: ITU

- Shielded box.
- Network simulator.
- Computers, (PC/workstation/notebook).

Personnel competency matrix (main skills)

Laboratory manager: knowledge of mobile communication systems architecture, radio access techniques, communication protocols and networking, strong knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: basic knowledge of mobile communication systems architecture, radio access techniques, communication protocols and networking, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test Campaign Operator: basic knowledge of mobile communication systems architecture and communication protocols recommended.

Technical experts (not mandatory, recommended): strong knowledge of mobile communication systems architecture, radio access techniques, communication protocols and networking.

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

Dimensions

Standard dimensions and layout is needed.

Electrical requirements

Standard power supply is needed.

Environmental requirements

NA

Safety

NA

I Power efficiency laboratory (PWE)

Scope of the laboratory

Energy efficiency improvement is contributing to the reduction of global gas emission associated with the production and use of electricity. In the next years electricity demand will grow fast producing a growth also in the use of raw materials that is necessary to counteract. A significant reduction in energy consumption is considered as a mandatory target.

In fact energy saving is the most cost-effective way to increase security of supply and reduce import dependency; therefore, substantial demand-side measures and targets should be adopted by all the countries.

As a general principle and where appropriate, the energy consumption of energy-related products in stand-by or off-mode should be reduced to the minimum necessary for their proper functioning.

Office equipment and consumer electronics are often powered by external power supplies which convert electricity from the main power sources. The power conversion efficiency of such external power supplies is another important aspect of the energy performance of such products, and thus external power supplies are one of the priority product groups for which Eco design requirements have been established.

The PWE has the scope to verify the compliance of the equipment respect to the electrical requirements prescribed by the European Commission in accordance to Regulation No 1275/2008/EC, to Regulation No 278/2009/EC and to the voluntary agreements. Code of Conduct Energy-related products that comply with the Eco design requirements laid down in implementing measures to this Directive should bear the 'CE' marking and associated information, in order to enable them to be placed on the internal market and move freely.

List of testing services

Evaluation of power consumption and power efficiency conversion for information technology and telecommunication equipment

Reference standards

- DIRECTIVE 2009/125/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL 21 October 2009 – establishing a framework for the setting of Eco design requirements for energy-related products.
- **(EC) No 1275/2008 17 December 2008** – COMMISSION REGULATION (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the

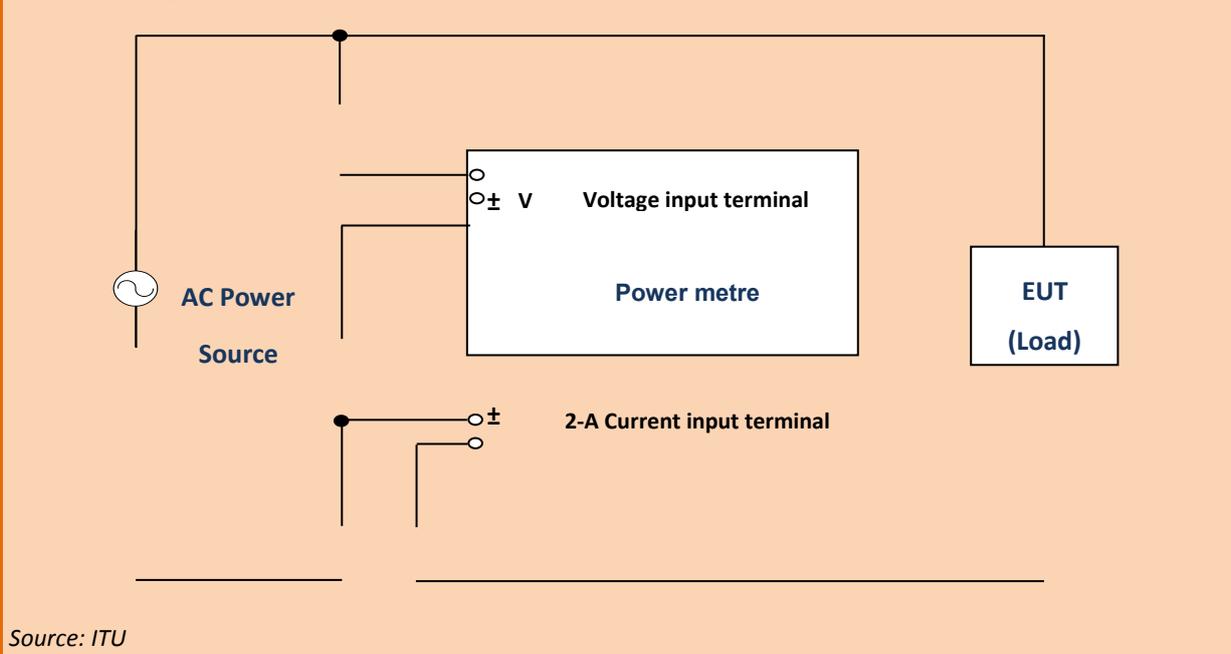
Council with regard to Eco design requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment.

- **(EC) No 278/2009 6 April 2009** – COMMISSION REGULATION (EC) Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Eco design requirements for no-load condition electric power consumption and average active efficiency of external power supplies.
- **EN 62301 I Edition: 2006-11** – Household electrical appliances – measurement of standby power.
- Code of conduct on energy consumption of broadband equipment version 4 – 10 February 2011.
- Code of conduct on energy efficiency of digital TV service systems version 8 – 15 July 2009.

Test equipment set up and instrumentation

In this section the test equipment set up is described including the instrumentation list (main components). Additional general conditions for measurements or validation is included after test equipment table below.

Figure I.1: (EC) No 1275/2008 test set-up



Source: ITU

Figure I.2: (EC) No 1275/2008 detail of test set-up for low current

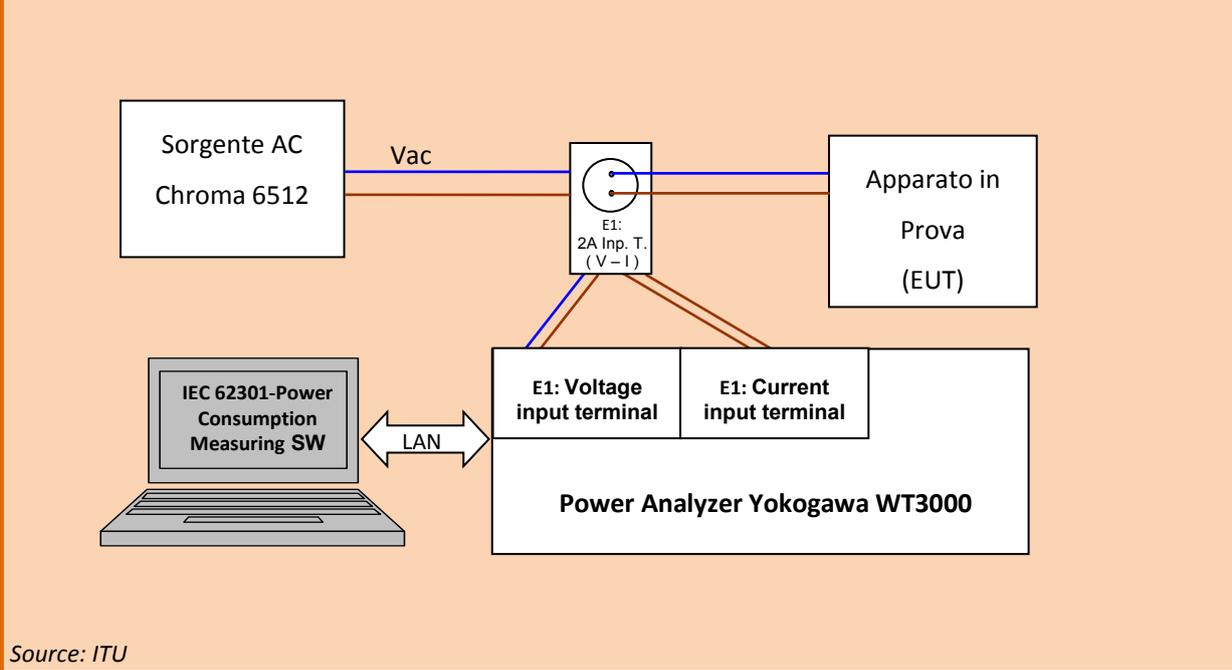
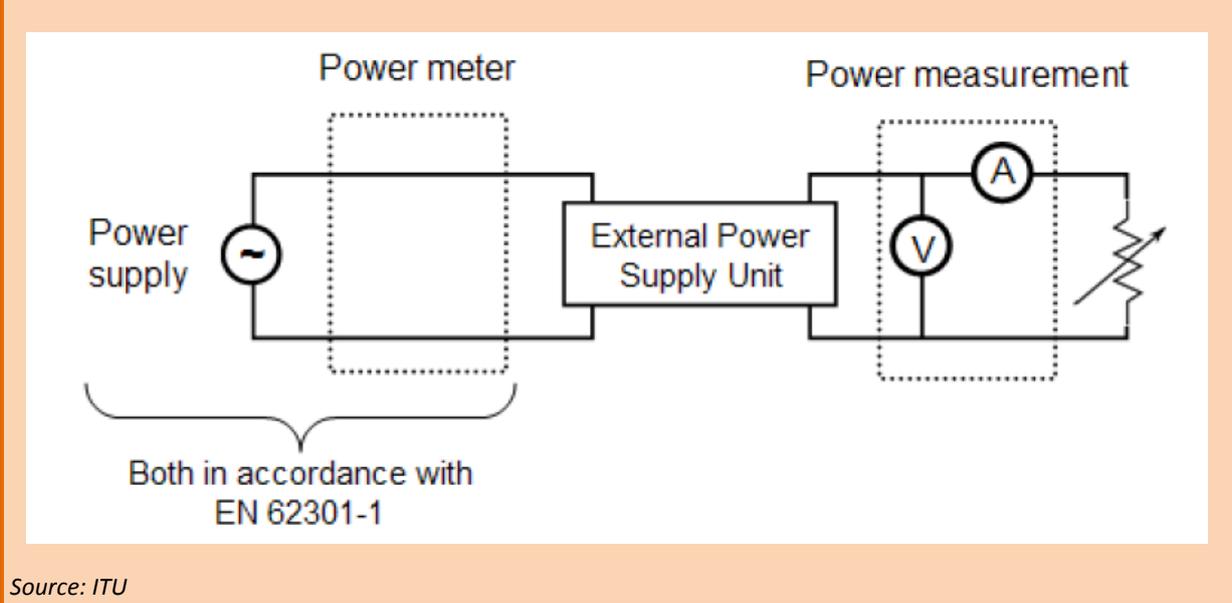


Figure I.3: (EC) No 278/2009 test set-up



Main test equipment used by the laboratory:

- power analyser;
- AC source;
- anemometer;
- thermo-hygrograph;
- AC/DC electronic loads;
- millimetres.

Personnel competency matrix (main skills)

Laboratory manager: Equipment knowledge, ICT network and systems architecture, strong knowledge of quality aspects (knowledge of ISO/IEC 17025:2005 recommended), basic knowledge of main foreign languages.

Test campaign responsible: Electronics, basic knowledge of communication systems architecture and radio access techniques, basic knowledge of quality aspects, strong capability to train and coordinate campaign operator work.

Test campaign operator: basic knowledge of equipment and their main operation states recommended.

Technical experts (not mandatory, recommended): Physics, chemistry, mechanical engineering. Experts support laboratory manager and campaign responsible in head and body tissue liquids management as well as in laboratory hardware/robots management and installation.

On-site requirements

In the following some information related to the general conditions for measurements (EN 62301) are reported:

Unless otherwise specified, measurements shall be made under test conditions and with equipment specified in: Test room, power supply, supply voltage waveform, power measurement accuracy.

Test room

The tests shall be carried out in a room that has an air speed close to the appliance under test of $\leq 0,5$ m/s. The ambient temperature shall be maintained at (23 ± 5) °C throughout the test.

NOTE: The measured power for some products and modes may be affected by the ambient conditions (e.g. luminance, temperature).

Power supply

Where the EN62301 standard is referenced by an external standard or regulation that specifies a test voltage and frequency, the test voltage and frequency so defined shall be used for all tests.

Where the test voltage and frequency are not defined by an external standard, the test voltage and test frequency shall be:

230 V \pm 1 per cent

50 Hz \pm 1 per cent

If the appliances are to be connected to three phases and the test voltage and frequency are not defined by an external standard the test voltage and test frequency shall be:

400 V \pm 1 per cent

50 Hz \pm 1 per cent

Supply voltage waveform

The total harmonic content of the supply voltage when supplying the appliance under test in the specified mode shall not exceed 2 per cent (up to and including the 13th harmonic); harmonic content is defined as the root-mean-square (r.m.s.) summation of the individual components using the fundamental as 100 per cent.

The ratio of peak value to r.m.s. value of the test voltage (i.e. crest factor) shall be between 1,34 and 1,49.

Power measurement accuracy

Measurements of power of 0,5 W or greater shall be made with an uncertainty of less than or equal to 2 per cent at the 95 per cent confidence level. Measurements of power of less than 0,5 W shall be made with an uncertainty of less than or equal to 0,01 W at the 95 per cent confidence level. The power measurement instrument shall have a resolution of:

- 0,01 W or better for power measurements of 10 W or less;
- 0,1 W or better for power measurements of greater than 10 W up to 100 W;
- 1 W or better for power measurements of greater than 100 W.

For appliances connected to more than one phase, the power measurement instrument shall be equipped to measure total power of all phases connected.

J Quality of materials laboratory (QML)

Scope of the “materials testing” laboratory

The laboratory is involved in the evaluation of properties and field performances of materials employed in ICT networkS and equipment. Physical and chemical tests are carried out to verify network materials compliance to technical specifications, to evaluate weathering resistance and to support end of life disposal. A few aspects concerning environmental impact and safety of materials in field can also be investigated. The capabilities are applied to the materials in the following steps of their lifecycle:

- before introduction, as a part of the qualification process;
- after type approval for the surveillance of dispatched lots;
- during field employment in case of early degradation or failures;
- at the end of life to find out the best disposal routes.

List of “materials testing” laboratory services

- Plastic and composite materials testing: these are primarily applied to cable insulations and sheaths, pipes, polymeric coatings and paints, housings for telephones and network boxes, glass reinforced thermosetting poles, etc.
- Metallic materials testing: these tests concern cable conductors and shields, connectors, ground ropes and bars, load bearing accessories for aerial network, manholes, etc.
- Climatic and weathering tests: to evaluate any deleterious effect of the environment on the performances of ICT equipment and on the lifetime of constituent materials (corrosion, degradation, failures, etc.).
- Safety and environmental tests: to evaluate any deleterious effect of ICT materials on the environment, including safety of workers. Typical examples are volatile emissions from heat shrinking sleeves and leaching of preservative chemicals from impregnated wood poles.

Reference standards

Most tests have to be carried out according to standard test methods, as prescribed in the technical specifications of the ICT product. Since material specimens have often to be obtained from an industrial product, compliance can be a difficult task: e.g. dumbbell tensile test specimens obtained from a cable sheath may not have uniform thickness or retain a light curve shape. Reference standards are part of the following two main categories:

- ISO, CEN, ASTM standard for materials testing.
- IEC standard for electrical and electronic equipment testing (ETSI for ICT equipment).

Test equipment and instrumentation

Main test pieces of equipment are the following:

- **Infrared spectroscopy** for the identification of chemical composition of plastic materials and main additives.
- **Thermal analysis:** DSC (differential scanning calorimetry – typical range -150 °C – + 700 °C) to determine fusion and transition temperatures, thermal stability (Oxidation Induction Time for polyolefin); TG (Thermogravimetry – typical range – room temperature – 1000 °C) for inorganic reinforcement content of plastic compound (e.g. glass fibers) or carbon black percentage of stabilized “black” thermoplastic compounds.
- **Optical microscopy:** for coating thickness measurement and microstructure evaluation as well as defects.
- **Electronic microscopy** with EDX analysis for semi quantitative analysis of metals and alloys and morphology examination at high magnification to evaluate the causes of failures.
- **Mechanical testing equipment** (tensile, flexural, compressive tests).
- **Fire testing equipment:** for small size specimen classification of fire resistance behaviour, with reference to UL 94 standard or alike.
- **Climatic chambers:** to support equipment classification with reference to “climatic classes” specified in ETSI 300-019 series. In cooperation with other LAP laboratories, these tests can be carried out on fully operating equipment, whose performance are continuously measured and the data transmitted are saved to ascertain any data loss.
- **Corrosion and accelerated weathering chambers** (e.g. salt spray).

Most tests are carried out through a sequence of operations or by the use of specific accessories but do not require a measurement bench. Fig. J.1, 2 and 3 illustrate a few steps to evaluate the microstructure of a spheroidal graphite iron employed for manholes production. A portion of the product (Fig.1) is mechanically cut and then abrasive particles are used to remove material from the sample surface until, the desired aspect is achieved.

Metallographic specimens are then “mounted” using an epoxy thermosetting resin, with low curing shrinkage, to assure superior edge retention (Fig.2). Mounting a specimen provides a reliable and safe way to hold a sample during the grinding and polishing operations.

After mounting, the specimen is wet ground to reveal the surface of the metal, then grinding is carried out with finer and finer abrasive media.

Silicon carbide abrasive paper is the traditional rough grinding technique and is often followed by finer grinding steps where diamond grit suspensions are dosed onto a reusable fabric pad throughout the polishing process. Diamond grit in suspension might start at 9 or 6 micrometre and finish at 1 micrometre.

Polishing with diamond suspension often gives finer results than using silicon carbide papers (SiC papers), since silicon carbide paper can “smear” over and hide porosities.

Grinding is usually followed by polishing with a slurry of alumina, silica, or diamond on a nap less cloth to produce a scratch-free mirror finish, free from defects and with minimal deformation remaining from the preparation process.

After polishing, microstructure defects such as inclusions and grain disuniformity can be seen with the microscope. The microstructural constituents of the specimen (Fig.3) are revealed by using a suitable chemical etchant (an electrolytic etchant might suit as well).

Figure J.1: Portion of a manhole covering broken in the load bearing capacity test (≥ 400 KN)



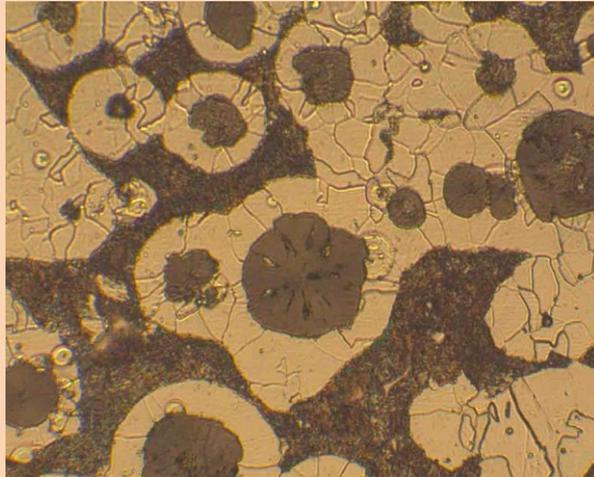
Source: ITU

Figure J.2: Specimens mounted in thermosetting epoxy resin



Source: ITU

Figure J.3: Optical microscope image (200 X) of the spheroidal graphite iron.



Source: ITU

Figure J.4: Dynamometer attachment to measure bursting strength



Source: ITU

Figure J.4 shows a dynamometer attachment to measure bursting strength of heat shrinkable sleeves used for cable joints. The determination of the bursting strength of rubber- or plastics-coated fabrics according to ISO 3303-1:2012, uses a mechanically operated steel ball.

Among laboratory facilities, an outstanding role is played by a so called LIMS (laboratory information management system) that increases efficiency and assures data consistency. Informative sample data are introduced when the test campaign is opened whilst results are loaded as soon as they are obtained. Tests parameters are aligned with laboratory capabilities i.e. personnel, test methods, equipment and

calibration status. Final tests reports emission is therefore easy and there is adequate confidence that all data have already been checked in the previous steps.

Personnel competency matrix (main skills)

Laboratory manager: physical and chemical materials properties, corrosion, degradation, environmental impact phenomena. Knowledge of ICT network architecture and of quality systems, (especially ISO/IEC 17025:2005). Intermediate knowledge of written and spoken English.

Test campaign responsible: physical and chemical materials properties and of pertinent test methods. Basic Knowledge of ICT network architecture and of quality systems applied to laboratory organization. Ability to evaluate and integrate in the test reports test results obtained by different laboratory operators. Basic knowledge of English.

Test campaign operator: Physical and chemical test methods; quality assurance of laboratory measurements.

On-site requirements

In the following, details related to the physical layout of the laboratory are reported.

The environmental requirements

Materials testing, especially for plastic and composite, usually requires the following environmental conditions:

- temperature range: $23 \pm 2^{\circ}\text{C}$.
- humidity 0.50 ± 5 per cent

When specimens conditioning is required before tests (e.g. 7 days at $+ 70^{\circ}\text{C}$ for fire resistance) or tests are not to be carried out at "room" temperatures, ovens and/or climatic chambers have to be employed.

For compliance measurements it is, however, required to set-up the measurement system in a controlled environment to maintain the liquid temperature with typical daily deviations of $\pm 1^{\circ}\text{C}$.

Safety

In the following, a few considerations relating the work safety in the laboratory are reported.

Physical hazards

These are a common source of injuries in many lab, namely where machines for sample preparation are employed. Machine may involve moving parts, sharp edges, hot surfaces and other hazards with the potential to crush, burn, cut, shear, stab or otherwise strike or wound technicians if used unsafely. Various safety measures exist to minimize these hazards, including formal authorization to use them only by trained personnel.

Chemical hazards

Acid, bases, heavy metals, solvents, highly reactive chemicals, gases and vapors are the main responsible for chemical hazards in the lab. Hazardous compounds might also originate from chemical reaction or combustion in fire resistance tests. Liquid nitrogen – when necessary (i.e. for thermal or electron microscopy analysis) can cause serious injuries for contact with skin and eyes or asphyxiation when quickly evaporates in small laboratory environments.

Fume hoods are the central element for the safe handling of hazardous substances in the laboratory and, as such, are a decisive factor when minimizing risk for all who work in the laboratory. Fume hoods typically protect only the user, and are most commonly used in laboratories where hazardous or noxious chemicals are released during activities. Two main types exist, ducted and recirculating. The principle is the same for both types: air is drawn in from the front (open) side of the cabinet, and either expelled outside the building or made safe through filtration and fed back into the room. The proper flow of air from the room into the hood is critical to its function. Much of fume hood design and operation is focused

on maximizing the proper containment of the air and fumes within the fume hood. In case laboratory air is expelled directly to the exterior of a building, large quantities of energy are required to run fans that exhaust the air, and to heat, cool, filter, control and move the air that will replace the air exhausted. Significant recent efforts in fume hood and ventilation system design have focused on reducing the energy used to operate fume hoods and their supporting ventilation systems.

To manage “residual risks”, several type of “protective personal equipment” should be provided to laboratory personnel. Surveillance of systematic use and periodic check for integrity are additional steps to assure that risks are kept as low as allowed by the “state of the art” in the field.

Gas leakage detection equipment has to be used to monitor, and alert the leakage of dangerous gases such as methane, acetylene (flammable and explosive), nitrogen, argon, helium (asphyxiant) etc. Electrovalves for the interception of the gases can be controlled by the leakage detection system to prevent concentration increase in the laboratory atmosphere and consequent danger.

Proper collection and disposal of exhausted chemicals and of material residues resulting from laboratory activities is an important issue. Although usually national or regional (i.e. EU) legislation regulates these matters, the laboratory organization plays an outstanding role in minimizing the amount of waste. This can be done by reducing the amount of sample and by physical separation of materials having different composition. Safety information should be provided to personnel in charge of support activities (i.e. clean-up, transport, security) to prevent any risk for injuries and pollution.

K Wi-Fi Laboratory (WIF)

Scope of a Wi-Fi laboratory

The need to acquire a Wi-Fi test laboratory for a telecommunications operator is mainly due to the need to ensure the quality of the Access Gateway and others Wi-Fi devices were sold in support of its commercial offer and, therefore, the quality of the service provided to its customers.

The scope of the test done in this kind of laboratory is to verify that the equipment under test meets the Wi-Fi specifications given to the product supplier and that the product complies with the IEEE 802.11 standards and with the country regulatory standards (for maximum radiated power, spectral mask, etc.).

The controlled test environment, in the laboratory (in the absence of uncontrolled interferences) also allows functional/performance comparisons to be made between products of different vendors before a new commercial competition, favouring the choice of the product best suited to the type of service offered.

List of laboratory testing services

Functional and performance – verification of main functionality of the EUT (equipment under test), like the GUI parameters settings related to the Wi-Fi interface, ENCRYPTION and verification of the maximum performance of the Wi-Fi radio in terms of throughput, at 2.4 GHz and 5 GHz.

Coverage – verification of the coverage of the EUT in a real environment, with furniture and other Wi-Fi networks, in terms of area extension in which the Wi-Fi service is available, at 2.4 GHz and 5 GHz.

Physical layer – verification, in conducted mode (with the EUT connected to the measurement setup using cables, attenuators, etc.) of the main parameters of the physical layer, like transmitted power, maximum power spectral density, spurs, spectral mask, etc., in 2.4 GHz and 5 GHz and DFS (radar detection) in 5 GHz band. The physical layer measurements can be extended to all devices that works in 2.4 GHz and 5 GHz bands, but don't use the Wi-Fi standard.

Reference standards

- **ETSI EN 300 328 V1.7.1** – Electromagnetic compatibility and radio spectrum matters (ERM); wideband transmission systems; data transmission equipment operating in the 2,4 GHz ISM

band and using wide band modulation techniques; Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive.

- **ETSI EN 301 893 V1.6.1** – Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive.
- **IEEE 802.11-2009** – (IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications – Amendment 5: Enhancements for Higher Throughput).
- **IEEE 802.11-2012** – (IEEE Standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications).

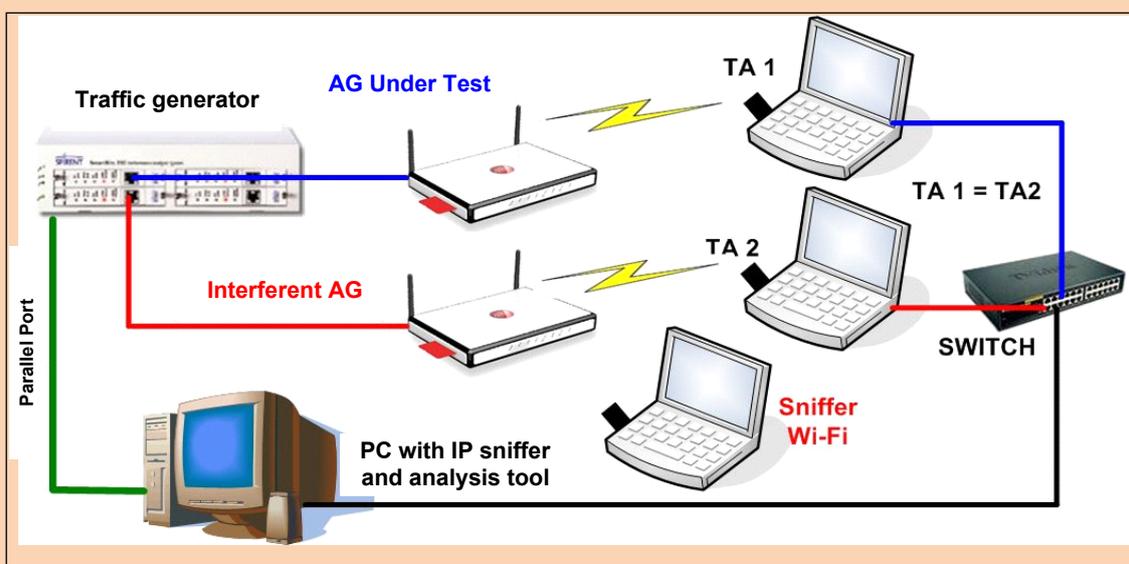
Test components and instrumentation

In this section the list of the test components and the instrumentation is reported, separately for each class of test.

Functional and performance test components/instruments:

- SHIELDED CHAMBER OR SHIELDED TENT (3m x 3m x 2.7m)
- NETWORK TRAFFIC GENERATOR/ANALYZER (GIGABIT ETHERNET)
- SPECTRUM ANALYZER (1 ÷ 6 GHz)
- WI-FI ANALYZER FOR PACKETS CAPTURE ON THE AIR
- REFERENCE ACCESS POINTS AND TERMINAL ADAPTERS (USB, PCMCIA, INTERNAL TO A PC) OF DIFFERENT IEEE802.11 STANDARD (b/g/h/n)
- DESKTOP AND NOTEBOOK WITH PCMCIA AND USB PORT AND INTERNAL WI-FI CARD

Figure K.1: Example of a measurement setup for performance test with an interferent

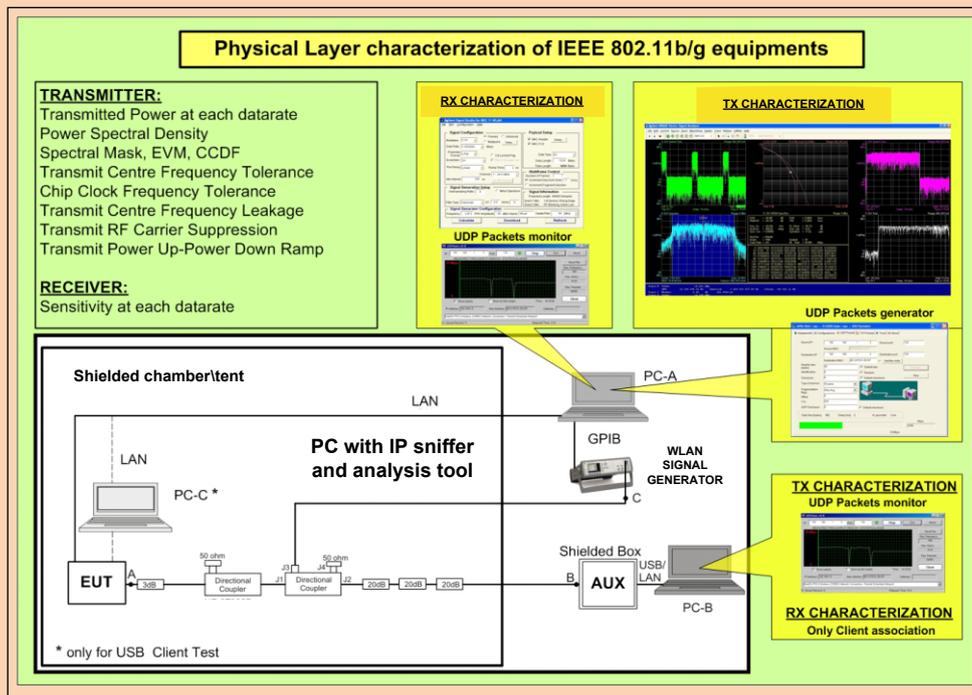


Source: ITU

- SOFTWARE PACKET GENERATOR AND MONITOR INSTALLED ON NOTEBOOK

- Wi-Fi ANALYZER FOR PACKETS CAPTURE ON THE AIR
 - REFERENCE ACCESS POINTS AND TERMINAL ADAPTERS (USB, PCMCIA, INTERNAL TO A PC) OF DIFFERENT IEEE802.11 STANDARD (b/g/h/n)
 - NOTEBOOK WITH PCMCIA AND USB PORT AND INTERNAL WI-FI CARD
- Physical Layer Test components/instruments
- SHIELDED CHAMBER or SHIELDED TENT (3m x 3m x 2.7m)
 - SAMPLING OSCILLOSCOPE (≥ 6 GHz)
 - SPECTRUM ANALYZER (1 ÷ 12.75 GHz FOR 2.4 GHz BAND AND 1 ÷ 26 GHz FOR 5 GHz BAND)
 - VECTOR SIGNAL ANALYZER
 - WIRELESS TEST SET FOR WLAN SIGNAL GENERATION
 - POWER METER GATED WITH DIFFERENT SENSORS
 - SYNTHETIZER (1 ÷ 6 GHz)
 - RADAR GENERATOR (AGILE SYNTHETIZER + ARBITRARY WAVEFORM GENERATOR)
 - CLIMATIC CHAMBER
 - RF FIXED ATTENUATORS
 - RF VARIABLE ATTENUATORS (MANUAL OR PROGRAMMABLE CONTROL)
 - RF CABLES
 - RF POWER SPLITTERS
 - RF DIRECTIONAL COUPLERS
 - RF 50 OHMS TERMINATIONS
 - RF TERMINATION ADAPTERS
 - VECTOR NETWORK ANALYZER (1 ÷ 6 GHz)
 - NOTEBOOK WITH PCMCIA AND USB PORT AND INTERNAL WI-FI CARD
 - MEDIA CONVERTER (ELECTRICAL\OPTICAL\ELECTRICAL)

Figure K.2: Example of a PHY measurement setup for IEEE 802.11 b/g equipment



Source: ITU

Personnel competency matrix (main skills)

Laboratory manager: Electronics measurements, Microwave and RF components, strong knowledge of Wi-Fi standards for radio access techniques and regulatory standards, basic knowledge of main foreign languages.

Test campaign responsible: Electronics measurements, microwave and RF components, strong knowledge of Wi-Fi standards for radio access techniques, strong capability to train and coordinate campaign operator work, basic knowledge of main foreign languages.

Test campaign operator: basic knowledge of RF measurements and Wi-Fi standards.

On-site requirements

In the following some information related to the physical layout of the laboratory are reported.

Dimensions

A laboratory of 8m x 5m could be enough to place a shielded chamber\tent of 3m x 3m and have room enough for tables for instruments and for activities outside the shielded chamber\tent.

Performance and physical layer test can be done using the same shielded chamber\tent, but not at the same time. Two shielded chambers\tents is better, and allows to parallelize the tests.

Air conditioning is required in the shielded chamber to maintain the temperature at the desired level, for tests that require the operator presence inside for some hours, but is not mandatory.

Electrical requirements

Electrical outlets shall be installed inside the shielded chamber\tent and the powering shall be filtered to avoid the interference picked outside the chamber\tent by electrical cables. Filters are typically supplied by the chamber\tent vendors as an integral part of the chamber\tent, with different power, depending of

the equipment usage (i.e. single chamber\tent for performance and physical layer test or two chambers\tents, with separate usage).

L Test plant

Scope of a test plan

As already mentioned several times in the main document, a conformance test centre, offering several conformance testing services on many different areas of ICT, has the necessity to use test plant in order to reproduce the real network to perform interoperability and end-to-end testing. Moreover in test plant it is possible to reproduce malfunction detected in the field and to find suitable workarounds.

Of course the functionalities of the test plant depend from the network to be emulated but, if the necessity is to reproduce the network of a medium/large operator, the location must be quite large. For this reason usually different test plant are realized or at least two: one for mobile and one for fixed network. This separation between fixed and mobile is also related to the different skill operating in the test plant and different operative procedures. However, in spite of the fact the two test plant are physically separated, it is important to connect the mobile and fixed test plant with appropriate transmission capabilities, in this way it is possible to test and verify also fixed-mobile service solutions like for example mobile backhauling.

Another important aspect is the interconnection of the test plants to the other test centre laboratories. In this way is possible to use the test plant, in a remote way, to emulate a service in correct working conditions or emulating a specific fault condition. A typical application is to connect a laboratory testing for example terminals to the test plant emulating a specific service (for example IPTV).

Fixed network test plant (TFP)

The functionalities emulated in a fixed test plant of course depends from the network choices, in the following a possible list is reported:

- BB Access
- NGN2 – GPON and VDSL2
- IP and ATM DSLAM
- Business and residential CPE
- SDH and xWDM transport
- GbE and IP/MPLS Metro Networks
- Layer 2 aggregation
- ATM
- Edge IP (PE/Access Routers, BRAS)
- IP Backbone (Terabit Routers and Gigabit Routers)
- TDM/IP Gateways and NGN (CL4 and CL5 nodes)
- IPTV Platform
- Data Centre Networking

Typical dimension for such a kind of test plant are around 1000 m² containing up to 100 racks and 200 pieces of equipment.

Mobile network test plant (TPM)

The functionalities emulated in a mobile test plant depends of course from the network choices, here a possible list is reported:

- LTE, UMTS and GSM Network
- Circuit and Packet Mobile Core Network
- VAS Platforms (IN, SMSC, MMSC, WAP GW, CMX, ...)
- IMS Platforms
- CL5 node

Typical dimensions for such a kind of test plant are around 2000 m² containing up to 200 racks and 400 pieces of equipment.

To manage and perform test in the test plant it is necessary a specific instrumentation:

- xDSL line simulators
- Spectrum Analyzers
- Noise Generators
- Arbitrary Wavelength Generators
- Traffic and Signaling Generators, network Generators (i.e. SDH, ...)
- Protocol Analyzers
- Diagnostic Software (e.g. ASCOM Monitor Master)
- Application Loading Software (e.g. HP LoadRunner)
- vMonitoring Software.

Appendix B: Cost evaluation

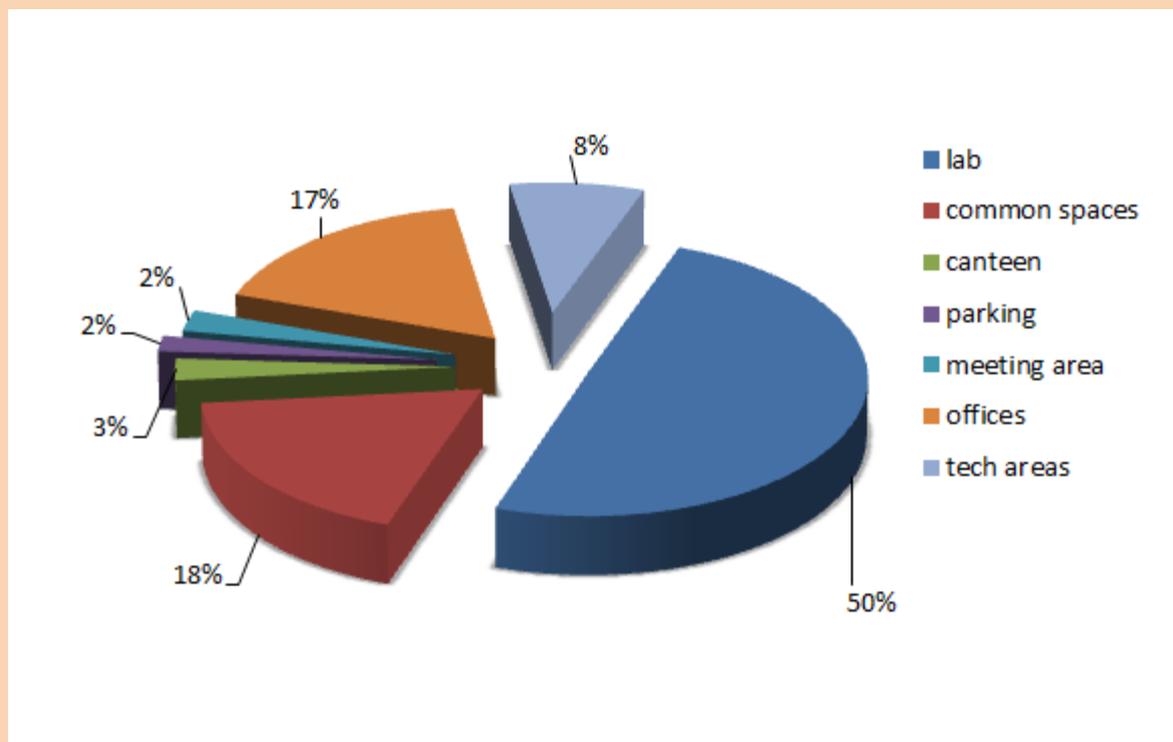
Cost evaluation

In this appendix some considerations and evaluations are provided to give general information in relation to the cost of a test centre as described in the main document.

Space allocation

The first aspect taken into consideration is the space allocation inside the test centre. A correct space balancing between offices, laboratories and common areas is very important to increase the test centre efficiency. A reasonable percentage allocation is given in the following figure.

Figure B.1.1: Space allocation



Source: ITU

Space allocation is a key factor to make a test centre suitable and efficient for a correct testing activity. The following subsections provide some advice on how to plan a cost effective space location.

Laboratories

As described in Appendix A, the laboratory dimensioning is strictly correlated with the testing activity performed. A general rule however is to try to avoid noisy instrumentation near office areas. As far as costs are concerned, a good solution is to keep the laboratory and test plant areas in the less expensive floor (for example in the basement) and use the higher floors, more comfortable and expensive, for offices.

Common spaces

Corridors and areas not used for specific activities can be used to install printers, faxes and coffee machines in order to make an efficient use of space allocation. Posters and table of contents can be shown in corridors to describe the single test activities performed in each testing department.

Canteen

The canteen must be dimensioned according to the number of employees and the national regulations in this matter. A good approach to avoid allocating a large area to the canteen is to organize different lunch time slots.

Parking

The parking must be dimensioned according to the number of employees and the national regulations in this matter. Internal parking is dimensioned only for the management structure.

Meeting areas

The correct dimensioning of the meeting areas is very important. In general it is useful to have different kinds of meeting areas according to the scope of the meeting such as:

- *A small auditorium* (50 seats) for plenary, corporate meeting, conventions, and large seminars and workshop
- *Medium size* meeting rooms (15 seats) for area and reporting meetings
- *Multimedia* meeting rooms (10 seats) for audio-video and remote conferences

Small (6 seats) meeting rooms for every day coordination meetings

An efficient meeting room planner (web oriented) must be adopted in order to avoid overhead cost to secretariat.

Offices

The correct office dimensioning is generally specified by national regulations taking into consideration illumination aspects and desktop positioning according to the videoterminal usage.

Some general rules should be used not to waste space allocation:

- single room for general manager (around 20 m²);
- single room for area managers (12 m²);
- double room for laboratory managers, senior engineers and project managers (12 m²);
- open space for test engineers.

In general, space needs can be reduced making use of teleworking and organizing open spaces with common area used alternatively by different employees fully equipped with ICT interconnections.

Technological area

These areas include the rooms used for heating/cooling machines, current distribution, network connections and so on. As described in the main document the correct dimensioning of these equipment, and the consequent space allocation, has a strong impact on cost.

Test centre cost evaluation

In the following some rough figures are provided taking into account the following general assumptions:

- cost estimated per year in Euro;
- test centre location: Italy (medium town);
- personnel of 180 people;
- estimation on cost of labour based on Italian average values;
- labour skill according to main document (management) and annex (skill competence matrix);

- laboratories as listed in appendix A;
- test centre total area: 11 000 m² (laboratories 5 400 m²).

The Opex for instrumentation maintenance is estimated as EUR 520 000 per year; of course it depends on the elements detailed in chapter 6.

Table 1: cost estimation (Euros per year)

personnel	12 600 000
location rent	700 000
utilities (energy, gas,water)	1 000 000
overhead per person (*)	9 500
opex instrumentation	520 000

(*) overhead=(location rent + utilities)/number of people

As detailed in the following paragraph, the total instrumentation assets estimated for the whole test centre is Euro 15 900.

LAB cost evaluation

An approximate evaluation of the different costs of each laboratory is given, taking also into account the overheads (the costs for location rent and utilities are calculated from the total cost, proportionally to the space allocation of the single laboratories).

Table 2: Detailed cost estimation

Laboratory	Activity	m ²	Location Rent 1 000 €/year	Utility 1 000 €/year	Instrument Asset 1 000 €	Number of staff	Instrument Opex 1 000 €/year
SAR	Specific absorption rate lab	150	19	28	800	4	25
USX	User experience lab	130	17	24	100	6	0
BBA	Broadband access lab	300	39	56	1.400	7	5
VAS	Mobile value added services lab	40	5	7	0	3	0
EPS	Electrical safety and protection lab	80	10	15	1.200	4	25
ELA	Electroacoustic lab	250	32	46	800	4	5
EMC	Electromagnetic compatibility lab	300	39	56	1.600	5	5
RSL	Radio and signalling lab	250	32	46	2.000	12	10
PWR	Powering consumption lab	80	10	15	200	2	5
QML	Quality of material lab	250	32	46	1.300	6	15

Laboratory	Activity	m ²	Location Rent 1 000 €/year	Utility 1 000 € /year	Instrument Asset 1 000 €	Number of staff	Instrument Opex 1 000 €/year
WIF	Personal area network lab	170	22	31	500	5	5
TPF	Fixed test plant	900	117	167	3 000	33	120
TPM	Mobile test plant	2 500	324	463	3 000	55	300
management						10	
cross activities (*)						24	
TOTAL		5 400	700	1 000	15 900	180	520

(*) Cross activities: Project office, ICT management, Quality, Secretariat

The test centre has of course a significant asset in its instrumentation. It is very difficult to give a precise estimation of this asset, because it depends on the management strategies in budget yearly allocation and on the business model adopted by the test centre.

In the table, some figures are given for a test centre performing a typical testing activity for a large national operator and covering all the main technological areas. The cost of equipment tests especially in the test plants, are not considered as usually the equipment are provided by the vendor with no extra charge.

Of course the instrumentation assets change dramatically if the test centre is an independent test centre focalized only on a part of the reported testing areas. The same applies for the personnel, utilities and space allocation.

The total Capex cost for the instrumentation (i.e., what we here called “instrumentation asset”) is usually distributed on several calendar years, because usually a Test Centre is not started from scratch.

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CENELEC EN 62209-1:2006 – Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz).

IEC 62209-2:2010 – Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz).

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ETSI TS 101 388 V1.3.1 “Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) – European specific requirements” (2002-05)

Broadband Forum (BBF) TR-100 “ADSL2/ADSL2plus Performance Test Plan” (2007-03)

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IEC 61000-4-2, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test

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IEC 61000-4-4, Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test

IEC 61000-4-5, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-6, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields instrumentation, for power supply systems and equipment connected thereto

IEC 61000-4-8, Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test

IEC 61000-4-9, Electromagnetic compatibility (EMC) – Part 4-9: Testing and measurement techniques – Pulse magnetic field immunity test

IEC 61000-4-10, Electromagnetic compatibility (EMC) – Part 4-10: Testing and measurement techniques – Damped oscillatory magnetic field immunity test

IEC 61000-4-11, Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity test

IEC 61000-4-16, 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 immunity test. For example, the European telecommunications Standardization Institute development and publishes conformance standards for telecommunication equipment to pass the following tests

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Recommendation ITU-T K20 – Resistibility of telecommunication equipment installed in a telecommunications centre to over voltages and over currents

Recommendation ITU-T K45 – Resistibility of telecommunication equipment installed in the access and trunk networks to over voltages and over currents

Recommendation ITU-T K44 – Resistibility tests for telecommunication equipment exposed to over voltages and over currents – Basic Recommendation

TBR8: ISDN; 3,1kHz telephony teleservice. Attachment requirements for handset terminals

TBR38: Public Switched Telephone Network (PSTN); “Attachment requirements for a terminal equipment incorporating an analogue handset function capable of supporting the justified case service when connected to the analogue interface of the PSTN in Europe”

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CISPR 16-1-3 Part 1-3: Ancillary equipment – Disturbance power

CISPR 16-1-4 Part 1-4: Antennas and test sites for radiated disturbance measurements

CISPR 16-1-5 Part 1-5: Antenna calibration test sites for 30 MHz to 1 000 MHz

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CISPR 16-2-4 Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements

CISPR 16-4-2 Part 4-2: Uncertainties, statistics and limit modeling – Uncertainty in EMC measurements

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IEC 61000-6-4 Part 6-4: Generic standards – Emission standard for industrial environments

IEC 61000-6-1 Part 6-1: Generic standards – Immunity for residential, commercial and light industrial environments

IEC 61000-6-2 Part 6-2: Generic standards – Immunity for industrial environments

CISPR 11 Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement

CISPR 12 Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of off board receivers

CISPR 13 Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement

CISPR 14-1 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission

CISPR 14-2 Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 2: Immunity – Product family Standard

CISPR 15 Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment

CISPR 20 Sound and television broadcast receivers and associated equipment – Immunity characteristics – Limits and methods of measurement

CISPR 22 Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement

CISPR 24 Information technology equipment – Immunity characteristics – Limits and methods of measurement

CISPR 25 Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of onboard receivers

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3GPP TS 36.521-3 "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) conformance specification Radio transmission and reception Part 3: Radio Resource Management Conformance Testing"

3GPP TS 34.108 "Common Test Environments for User Equipment (UE) Conformance Testing"

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List of acronyms

AC	Alternate Current
CAPEX	Capital Expenditure
CEI	Comitato Elettrotecnico Italiano
CFL	Compact fluorescent lamps
DC	Direct Current
EN	European Norm
EUT	Equipment Under Test
GSM	Global System for Mobile communication
HSDPA	High Speed Downlink Packet Access
ICT	Information and Communications Technologies
IEC	International Electrotechnical Commission
ILAC	International Laboratory Accreditation Cooperation
ISO	International Organization for Standardization
IUT	Implementation Under Test
LED	Light emitting diode
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
NGAN	Next Generation Access Network
OPEX	Operating Expenditure
OSI	Open System Interconnection
PICS	Protocol Implementation Conformance Statement
PIXIT	Protocol Implementation eXtra Information for Testing
TCO	Total cost of ownership
WSN	Wireless Sensor Network