2 Research and Development of Calibration Technology
2-1 ISO/IEC17025 Management System in NICT Calibration

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Electromagnetic Compatibility laboratory of NICT acquired the JCSS and ASNITE accreditation based on the ISO/IEC17025 in March 2006, which is an international standard for the competence of calibration laboratories. Since then, we have conducted improvement and maintenance of the management system. The scope of the accreditation has also been updated during the 10 years from the first certification in 2006. In this report, we describe the current scope of accreditation and activities for the ISO/IEC17025 program.

1 Introduction

Calibration services for measuring instruments provided by NICT date back to 1952, controlled by the predecessor organization, the Radio Research Laboratory (Ministry of Posts and Telecommunications). The calibration services in early years mainly targeted the testing equipment used in radio stations, and the calibration items have since been based mainly on the specifications laid down by the Radio Law. To enhance the calibration coping capacity of the organization and provide internationally acceptable high standard of calibration results, the Electromagnetic Compatibility Laboratory of the Applied Electromagnetic Research Institute (at the time called the EMC center of the Wireless Communication Division) acquired JCSS (based on ISO/IEC17025[1]-[3]) and ASNITE accreditation in March 2006[5]. The term "accreditation" is used in the following part of this report, because the National Institute of Technology and Evaluation (NITE)'s accreditation center (hereafter referred to as IAJapan) calls the JCSS-registered international MRA-compliant[4] business an "accredited calibration laboratory." JCSS is a system managed by IAJapan to guarantee traceability to the requirements laid down by the Measurement Act, which registers calibration laboratories after examining if it is compliant with the Measurement Act-related regulations and satisfies the requirements put forward by ISO/IEC17025. ASNITE is another accreditation program, developed and operated by IAJapan, whose main objective is to cover the areas that fall outside the targeted domain of JCSS. The accreditation criteria are the same with those used in JCSS, i.e. ISO/IEC17025[6].

ISO/IEC17025 is an international standard that defines the capabilities of calibration laboratories, and stipulates requirements in terms of management and technical capacity. The accreditation laboratory is required to comply with the requirements in the construction, implementation, and maintenance (improvement) of its management system. NICT, after acquisition of the accreditation, has provided JCSS- and ASNITE-based calibration services, with due effort to maintain and improve the management system, e.g., the scope of accreditation has been properly updated for each calibration system revision and each calibration item addition.

This article reports on the procedures and revised contents of accreditation that have been taken after the acquisition of the accreditation.

2 Acquisition of accreditation

The efforts toward acquiring JICSS and ASNITE accreditation started in 2004, aiming at international recognition and quality upgrade of the calibration results provided by NICT, as well as enhancing NICT's calibration capabilities. NICT successfully gained both accreditations (both are international MRA compliant) in 2006. The scope of accreditation at the time of initial acquisition is shown in Table 1

Although there are several accreditation bodies other than JCSS in Japan, NICT prefers IAJapan for submitting applications to acquire ASNITE accreditation because it covers all the range of calibration items needed.

Table 1 Scope of accreditation at the time of acquisition

Type	Range of calibration
DC Voltage Source	1, 10, 100 V
DC Current Source	100 mA, 1, 10 A
AC Voltage Source	100 V at 50, 60, 400 Hz
AC Current Source	50, 60 Hz at 1, 10 A
AC Current Source *ASNITE	0.2, 2, 20, 200 mA at 1, 5, 10 kHz
High frequency power measureing equipment	1 mW at the following frequencies: 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10, 11, 12, 13, 14, 15, 16, 17, 18 GHz
	10 W at the following frequencies: 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0 GHz
	0.1, 0.5, 1, 3, 5, 7, 20, 30, 50 W at 100 MHz
Attenuator	10, 20, 30, 40, 50, 60, 70, 80, 90 dB at 10, 30, 100, 500 MHz, 1, 5, 10 GHz
	18 GHz: 10, 20, 30, 40, 50, 60 dB

Acquisition of the accreditation enabled NICT to establish calibration methods, calibration procedures, and uncertainty criteria that are fully compliant with ISO/IEC17025.

3 From the acquisition of accreditation up to now

3.1 Maintenance procedures

Maintenance of JCSS accreditation (same with ASNITE accreditation) requires continuous efforts, typically: 1) continuous compliance with accreditation criteria, 2) notification of any modification without delay, and 3) proper procedures at the time of any modification of registered items[7][8].

In terms of 1), ISO/IEC17025 demands the laboratories to regularly calibrate the measurement standards and equipment (including secondary standards specified in JCSS) in an upper-level calibration laboratory (the interval is stipulated by Measurement Act). All the measurement standards and equipment in possession of our laboratory are served for calibration in the upper-level calibration laboratory at the given interval to guarantee traceability to national (international) standards, and to verify that measurement uncertainty is confined within the allowed range.

In addition, proper operation of the management system and maintenance/upgrade of technical capabilities are required. The management system now in place in NICT has been constructed based on the procedure manuals and other documents adhering to the requirements of ISO/IEC17025. These procedures, based on which calibration is performed, must also be verified to be conforming continuously to the required criteria. Therefore, these procedures are put under regular examination for their validity through internal audit, or by an accreditation body.

For maintenance and upgrading of technical capacity, proficiency testing[9] is also implemented on a regular basis (at least once every four years depending on the technical domain), which has reported satisfactory results.

In terms of 2), one of the major requirements is to notify any modification of the procedures to IAJapan, accompanied by the revised procedure documents. Replacement of equipment and change in calibration personnel also require notification. Note that a modification related to items of special importance — such as CMC (calibration and measurement capability), i.e. the minimum uncertainty, within the calibration range, certified by the calibration laboratory, and stated as such in the certificate — requires a renewal of registration (see description in 3) and simple notification will not suffice. Submissions for renewal of registration also include such items related to structure and name changes of organization and changes of personnel, in addition to revision of procedural docu-

Table 2 History of surveillance visit and registration renewal and the like

year	JCSS	ASNITE
2004	Preparation for application	
2005	New application	
2006		
2007	Surveillance visit	
2008	Registration renewal PL-system update	-
2009	Registration renewal and the like VC-system upgrade, AT range extension	
2010	-	-
2011	Registration renewal and the like	
2012	Relocation of calibration laboratory	
2013	Registration renewal and the like	
2014	VC range extension, PH system upgrade, AT range extension	
2015	-	Application for accreditation AL: new, VC: abolishment
2016	Surveillance visit	-

VC: Standard voltage and current generator
PL: High frequency power meter (1 mW)
PH: High frequency power meter (10 W)
AT: Attenuator
AL: Loop antenna for electromagnetic field

ments.

In terms of 3), even after JCSS and ASNITE grant a certificate, both organizations accept procedures for updating registration details, allowing upgrade of CMC, changes of calibration procedures, and addition of calibration items. Specifically, JCSS accepts renewals of registration, and ASNITE accepts accreditation applications (hereafter collectively referred to as "registration renewal and the like"). The registration renewal and the like will be further described later in this report.

3.2 Surveillance visit

JCSS and ASNITE stipulate post-certification inspection performed by an accreditation body to guarantee compliance with ISO/IEC17025: a partial inspection after one year from the first accreditation, and a full inspection every two years from the first accreditation[7][8].

Table 2 summarizes the history of surveillance visits and renewal registrations and the like.

The first surveillance visit was carried out by IAJapan (JCSS and ASNITE) in 2007, one year from the granting of accreditation. The surveillance visit includes on-site inspection which pointed out many problems: 4 nonconformities and 2 two observation items by JCSS, and one nonconformity and 2 observation items by ASNITE. These problems were pointed out mainly due to deficiency of documents and equipment management.

Nonconformity in this context means noncompliance with ISO/IEC17025 requirements (i.e. lack of evidence to verify conformance) and the observation item indicates the situation where continuation of current conditions may lead to noncompliance, even if it is not considered noncompliant at the time of inspection.

Measures were immediately put in place to correct these problems, and the results were reported to IAJapan, which recognized compliance with ISO/IEC17025.

NICT received the second surveillance visit in 2015 (this time only JCSS). The smaller-than-stipulated number of surveillance visits (only twice in a period around 10 years) is due to the fact that NICT went through procedures for registration renewals and the like five times during this period (see the description below).

3.3 Registration renewal and the like

During around the 10 years since NICT gained accreditation, it carried through the formalities of registration renewal and the like aiming at upgrading CMC, modification of calibration procedures, and addition of accredited items. Major items that constitute registration renewal and the like are described below. As in the case of first accreditation examination, submission for renewal entails both documentary examination and on-site review.

3.3.1 Update of the calibration system (2007)

An application for accreditation renewal was made when the high frequency power meter (1mW) calibration system was refurbished.

The new calibration system adopted the method called "simultaneous comparison by replacement," which makes the system highly accurate with much less interference from the reflection and variation of the signal source[10]. This upgrade also improved CMC.

3.3.2 Update of the calibration system and expansion of calibration range (2009)

A renewal application was made when the system for calibrating the standard voltage and current generator was changed, which yields improved CMC and an addition to the range of attenuator (30 MHz, 1-9 dB).

To achieve improvement in CMC, the digital multimeters used in the calibration system were replaced with new ones, and the method to construct an uncertainty

budget (evaluation) sheet was reviewed. A new attenuator (30 MHz), capable of 1dB-step attenuation adjustment, was introduced in addition to the standard attenuator (10 dB-step adjustment). Establishing traceability of this equipment to the national standard paved the way to expand the range of calibration.

3.3.3 Relocation of calibration laboratory (2011)

Building No.3 of NICT headquarters was demolished in 2011 and a new No.3 building was constructed. Our laboratory, including the calibration laboratory, was relocated from the old No.2 building to the new No.3 building.

Renewal of registration and the like were performed to reflect the relocation and other changes. The new building is equipped with, in addition to the study room, many research facilities such as an experimental laboratory and large and small anechoic chambers. The large anechoic chamber is used, for example, to calibrate antennas, e.g., a loop antenna for an electromagnetic field.

3.3.4 Update of the calibration system and expansion of calibration range (2013)

Another application for registration renewal was made to reflect the following changes: extension of the calibration range for standard voltage and current generators, CMC upgrade accompanied by modification of high frequency power meter (10 W) calibration systems, and calibration range extension of attenuators (due to frequency interpolation).

To extend the calibration range, traceability to the national standard was newly established for three measurement items of standard voltage and current generators: DC current 10 mA, AC voltage 10 V, and AC current 0.1 A.

In the conventional high frequency power meter (10 W) calibration system, calibration values were determined by replacing the standard high frequency power meter (calibrated at 10 W in the upper-level calibration laboratory) with the target equipment, which at times produced a non-negligible uncertainty. To resolve this problem, we developed a new calibration system using the simultaneous comparison method [11]. The new system uses a 1mW high frequency power meter as the standard to improve CMC, and the range of calibration frequency was also extended (upper limit frequency was extended from 2 GHz to 9 GHz).

Before system modification, attenuator calibration was performed only at a fixed set of frequencies. The introduction of the frequency interpolation method (see reference [12]) enabled calibration at any desired frequency within the accredited frequency range.

3.3.5 Additional accreditation: loop antennas for electromagnetic field (2015)

Although NICT had provided calibration service for loop antennas for an electromagnetic field, with the development of a novel calibration method[13], NICT gained ASNITE accreditation using the new calibration system in 2015. Concurrently with the new accreditation, NICT abolished the ASNITE accreditation granted for calibrating standard voltage and current generators. Therefore, the only ASNITE accreditation granted to NICT at present is the one for loop antennas for electromagnetic fields.

3.4 Internal audit

Internal audit is a class of audit performed regularly (once in a year) by the calibration laboratory itself, the objective of which is to verify that the management system of the laboratory complies continuously with the ISO/IEC17025 requirements. Internal audit, especially those carried out in the incipient period after the acquisition of accreditation, detected major non-conformities that affect the management system in general, necessitating to implement follow-up audit to ensure better compliance. In recent years, the number of problems pointed out relating to the management system and technical issues have been significantly reduced.

3.5 Proficiency testing

Proficiency testing is an examination performed by an accredited implementation agency to verify if the calibration laboratory maintains technical competency. Any calibration laboratory has to undergo the test regularly (the interval differs by technical field, but at least once every four years) and must obtain satisfactory evaluation. Up to now, NICT has undergone the testing in each field, 6 times in all.

In case the results from a proficiency testing are not satisfactory, the calibration laboratory is required to implement adequate corrective measures and submit the evidence indicating that it regained the required competency.

The proficiency testing is held regularly every year in the technical areas where there are many accredited calibration laboratories. But in those areas with a fewer number of active laboratories, there is lesser chance of taking the testing, which presents major difficulties coping with it. In such areas where adequate proficiency testing is hard to find, it is allowed to introduce an alternative method, as a substitute to proficiency testing, under the agreement with IAJapan. For example, proficiency testing is not available

Table 3 Current scope of accreditation

Type	Range of calibration
DC Voltage Source	1, 10, 100 V
DC Current Source	10, 100 mA: 1, 10 A
AC Voltage Source	10, 100 V at 50, 60, 400 Hz
AC Current Source	0.1, 1, 10 A at 50, 60 Hz
High frequency power measuring equipment	1 mW at the following frequencies: 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10, 11, 12, 13, 14, 15, 16, 17, 18 GHz
	10 W at the following frequencies: 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 GHz
Attenuator	10, 20, 30, 40, 50, 60, 70, 80, 90 dB in the range from 10 MHz to 10 GHz 10, 20, 30, 40, 50, 60 dB in the range from 10 GHz to 18 GHz 1, 2, 3, 4, 5, 6, 7, 8, 9 dB at 30 MHz
Loop antenna for electromagnetic field *ASNITE	Loop radius 5 cm-30 cm 9 kHz～30 MHz

for loop antennas for electromagnetic fields because there is no accredited calibration laboratory other than NICT. NICT and IAJapan have come to an agreement that the following three-step procedure substitutes the proficiency testing: 1) Our laboratory calibrates the DUT loop antenna, 2) the DUT loop antenna is then calibrated by the National Metrology Institute (NMI), and 3) results from 1) and 2) are compared for evaluation.

3.6 Current scope of accreditation

Since the first accreditation, NICT has undergone the procedures of registration renewal and the like five times, aiming at a wider scope of accreditation and higher level of CMC. The current scope of accreditation is listed in Table 3.

Our laboratory has provided the types of calibration services based on the Radio Law, as well as those based on JCSS and ASNITE. Currently, however, our laboratory makes it a rule to provide calibration services only to those instruments/devices that belong to the Radio Law designated calibration agencies. The current scope of accreditation items are listed in Table 4. However, our laboratory provides calibration services even to those instruments/devices of non-designated calibration agencies if the range of calibration is out of service of designated calibration agencies (e.g. ≧110GHz range of a high frequency power meter).

Although provision of Radio Law-based calibration service does not require accreditation from JCSS and other agencies, NICT makes it a rule to incorporate, as far as possible, the ISO/IEC17025 requirements to maintain the calibration quality. To this end, NICT is preparing procedural documents abiding by the rules set out by JCSS and other agencies.

Table 4 Calibration items provided by NICT

Calibration of registered inspection business equipment	Frequency meter
	Spectrum analyzer
	Field strength meter
	High frequency power metor
	Voltage/current meter
	Standard signal generator
Entrusted calibration	Frequency meter
	High frequency power metor
	Attenuator
	Standard voltage and current generator
	Voltage/current meter
	Antenna Dipole antenna Bi-conical antenna Horn antenna DRGA
	Specific absorption rate probes
JCSS, ASNITE	See Table 3

4 Final notes

This report gives a historical summary, from the acquisition of JCSS and ASNITE accreditation up to now, of procedures and registration renewal and the like's implementation.

We have received many notes and suggestions from each surveillance visit and through the process of registration renewal and the like – both in documentary examination and on-site inspection. Internal audit has also pointed out many items to be improved. Through our corrective efforts, the management system has been improved.

Acquisition of ISO/IEC17025 accreditation demands a great effort. However, this is only the beginning: the follow-up efforts to maintain and improve the management system, and enhancement of technical ability are of greater importance. To provide calibration results of higher quality through the future, we are determined to pursue maintenance and improvement of the management system, as well as enhanced calibration capabilities.

In the face of the coming start of JCSS accreditation of loop antennas for electromagnetic fields, a series of procedures is under preparation for the migration from ASNITE to JCSS. Other renewals of registration items are also under planning, such as additional accreditation and modification of the calibration system.

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