SM1.4/AS4.20 EGU2015-9507

Status and development of the calibration programme

B. Doury, S. Nikolova, J. Marty, M. Zampolli, A. Kramer, M. Charbit, P. Labak

Disclaimer
The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO

CTBTO PREPARATORY COMMISSION

Introduction

Calibration is a requirement of the Seismological, Hydroacoustic and Infrasound IMS Operational Manuals and an important task towards credibility and trustworthiness of the IMS waveform networks. The objective of the calibration programme is to implement specifications laid in these documents through the development of a set of calibration standards, methods, tools and procedures used to assure the traceability of station performance (in terms of data quality) to a reference established at station certification, revalidation or upgrade.
The objective of this poster is to present the status and latest achievements on the calibration of the IMS Seismic, Infrasound and Hydroacoustic stations.

PTS Midterm Strategy 2014 – 2017

I The PTS is to "complet[e] its set of calibration standards and standardizing calibration equipment and procedures for all technologies. Calibration activities for the seismic network will be continued and be expanded to other technologies including hydroacoustic T phase stations and the infrasound network." (24) For the infrasound and hydroacoustic monitoring technologies, "the implementation of station calibration methods and procedures will help identify and remediate problems at the station"(29) and that the "PTS will aim at bringing the calibration of the IMS acoustic stations to the level of the other technologies of the network by the end of this MTS period."

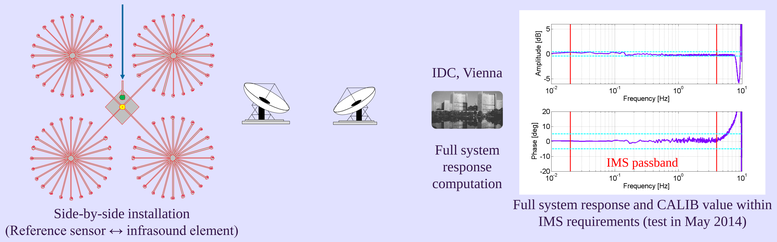
II The PTS is to "aim at bringing the calibration of the IMS acoustic stations to the level of the other technologies of the network by the end of this MTS period" through "calibration for acoustic conditioning assessment with open loop calibration of electronics and potentially with active calibration, […]". It also states that "at least one infrasound station is expected to fully meet these requirements by the end of 2017." (46.)

(CTBT/PTS/INF.1249)

II - Infrasound sensor calibration

Calibration technique

- Self-calibrating sensor calibrated on a regular basis
- Passive calibration of the full system response using side-by-side comparison
- May 2014: Method temporarily tested at one IMS infrasound station



- October 2014: WGB encouraged the PTS to pursue **integration** of this technique into the IMS infrasound network

This calibration technique is **cost-effective** and **minimizes the operational and engineering workload** for the PTS and Station Operators. It allows **full compliance** with the draft IMS Infrasound Operational Manual (CTBT/WGB/TL-11,17/17) and with PTS midterm objectives

Integration 2015 - Pilot station

Deployment of calibration capability at one pilot infrasound station:

- Installation of self-calibrating sensors at IS26
- Development of an end-to-end software solution for routine data processing and writing of results into the PTS CAMT database
- Long term testing of the calibration technique

Technique improvement & optimization

Based on performance of the calibration technique to be integrated at IS26:

- 2015: Improvement and optimization of full frequency response computational technique (method based on maximum likelihood estimation instead of coherence)

2015: Presentation of preliminary results at the ITW

2015 – 2016: Integration testing in laboratory for all existing infrasound station configurations

I - Calibration standards, methods and procedures

JCGM200:2012 – International Vocabulary of Metrology

calibration: operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication.

Draft IMS Operational Manuals for waveform stations

"Stations are provided with the means to carry out a calibration whose result can be compared against a reference that was established at the time the station was certified or when revalidation was completed on the station." They also state that stations are to be calibrated "on a schedule predetermined by the Technical Secretariat" or "when equipment maintenance has been performed that may affect the baseline calibration".

Scheduled (Yearly) Calibration

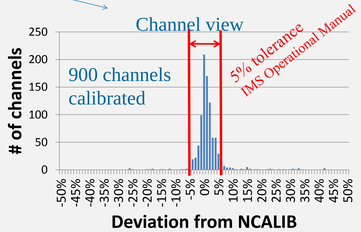
The implementation of IMS Operational Manual requirements for calibration was initiated in 2010 for the IMS Seismic network. Since 2012, every year all operating IMS seismic stations are scheduled for **electrical** calibration. Calibration is based on the response of the system to a known input signal (ground motion). Due to the linearity of the system, its response to any input signal can be predicted when its response to a suitable test signal is known.

Principle of electrical calibration: the seismic mass is excited with an electromagnetic force applied through the calibration coil built-in all seismometers deployed on the IMS network.

IMS Seismic Stations Scheduled for Calibration in 2014

Station view

	Scheduled	Calibrated	%
All	147	113	77%
Primary	42	40	95%
Auxiliary	105	73	69%
Array	31	28	90%
3component	116	85	73%



Scheduled calibration Looking forward

2014 – Pilot T-phase station H09 (Tristan da Cunha, UK):
First scheduled calibration of a hydro-acoustic T-phase station performed successfully.

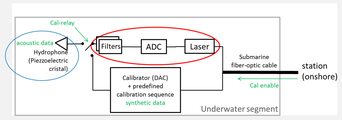
Code	Station	Calibration date	Scenario	Site	CALPER (s)	CALIB (nm/cnt)	NCALIB	Diff %	IN_SPEC
HA09	Tristan da Cunha, UK	17 Nov -19 Nov 2014	Random (600s) + sine 5Hz	H09N1	0.2	0.008335	0.00835	-0.18%	yes
					0.2	0.008117	0.00835	-2.80%	yes
					0.2	0.008224	0.00835	-1.51%	yes
				H09W1	0.2	0.006798	0.00835	-18.59%	no
					0.2	0.006785	0.00835	-18.74%	no
					0.2	0.006676	0.00835	-20.05%	no

2015 – All operating IMS T-phase stations are scheduled for calibration

2016/2017 – End-to-end calibration capability deployed at 4 IMS infrasound stations

Calibration of Hydrophones

The underwater electronics are housed in containers, which are typically located at depths between 1 – 2 km. The hydrophones are floated in the SOFAR channel. For each channel, a hydrophone is connected to the analog-to-digital (A/D) conversion electronics, which digitizes the data and sends it to shore via a fibre-optic link.



Calibration of underwater electronics

Open-loop calibrations of the at-sea deployed system can be triggered from shore at any time:

1. the hydrophone is temporarily excluded by a switch from the rest of the system;
2. a digital-to-analog converter injects calibration waveforms into the input of the electronics;
3. the system response to these known input waveforms, which have passed through the filters and digitizers, is transmitted to shore via the fibre-optic link where it is recorded;
4. The measured Transfer Function is compared with the baseline (from installation time).

Calibration of hydrophones

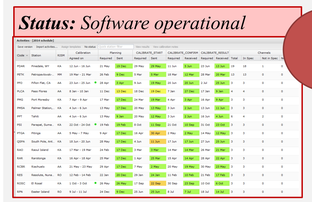
Before installation, the hydrophones are calibrated in pressurized tanks which reproduce the same environmental conditions (ambient pressure and temperature) in which the sensor is required to survive for its design life. The ambient pressure at 2 km depth is 200 atmospheres. Previous studies have found the sensors to be stable and well within the calibration tolerance prescribed by the Treaty.

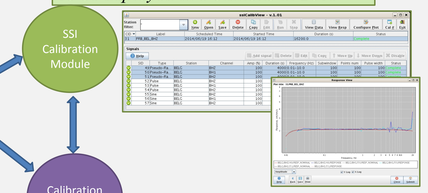
Supporting software

CAMT
Calibration Activities Management Tool

Generate, modify, store, manage, report and display the calibration schedule for IMS primary and auxiliary seismic stations and the status of the calibration activities at the IMS stations.

Status: *Software operational*





SSI Calibration Module

Extends SSI with calibration capability. It allows Station Operators and PTS staff to trigger calibration on the device, record the result, and calculate the response.

Status: *In testing.*
To be deployed at 3 stations in 2015

Calibration toolbox

Cover PTS technical needs and processes inherent to the evaluation, analysis, consolidation and documentation of calibration and orientation activities

Status: *First developments in 2015*

Infrasound technology - Pilot Interlaboratory Comparison Study 2015

Note: a poster dedicated to this project will be displayed at SnT2015

Scope
State-of-the-art review of methods for the characterization, testing and evaluation of microbarometers

Participants
Commissariat à l'énergie atomique (France)
Sandia National Laboratories (USA)
University of Mississippi (USA)

Coordinator
Provisional Technical Secretariat

Objective
On a midterm basis, this Pilot Study will be reiterated with extended sensor specifications and potentially additional participants. In the long term, it is foreseen that this Pilot Study is used as a baseline to perform future Inter-Laboratory Comparisons in order to assess calibration and measurement capabilities, validate test methods and determine the characteristics of new instruments.

International standards for the infrasound technology

Seismic calibration & orientation – Reference Sensor — IMS/OSI project

Business case
To this date, the on-site calibration of IMS seismic sensors has relied solely on the **electrical calibration** technique. By reviewing current practices, the PTS identified the following items:

- Lack of traceable indicators for the evaluation of performance (in terms of data quality);
- Several limitations are inherent to the electrical calibration technique;
- OSI also has a need for a traceable calibration method for its seismometers, to issue certification documentation for SAMS in case of an on-site inspection.

Objectives

- To develop a new technique based on a field kit to calibrate and orientate IMS and OSI seismometers using ambient noise and a reference seismometer
- To approach - or, if possible, to achieve - metrological traceability for the calibration and orientation of IMS seismometers

Traceability chain